INDUCTION COILS

AND

COIL-MAKING

ALLSOP

SPON

INDUCTION COILS

AND

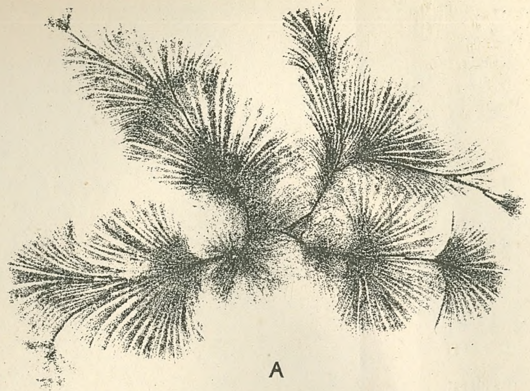
COIL - MAKING

ALLSOP

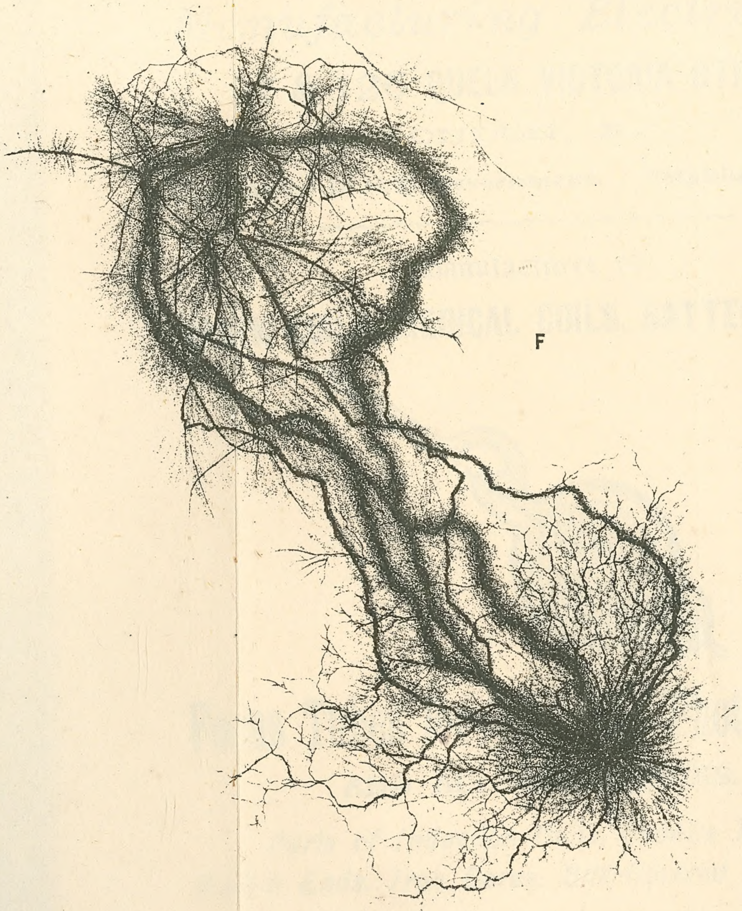
INDUCTION COILS

AND

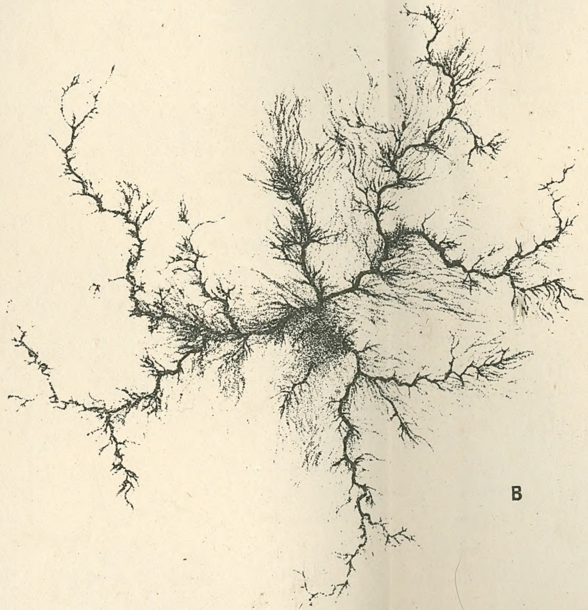
COIL-MAKING



A



F

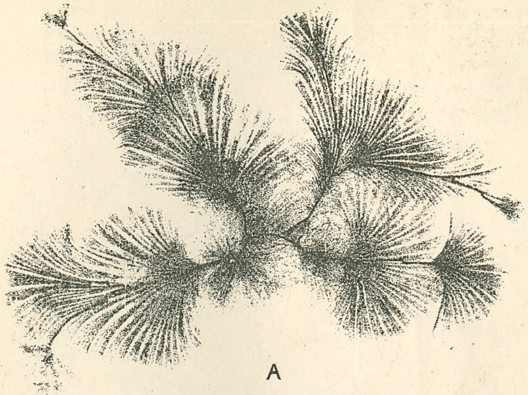


B

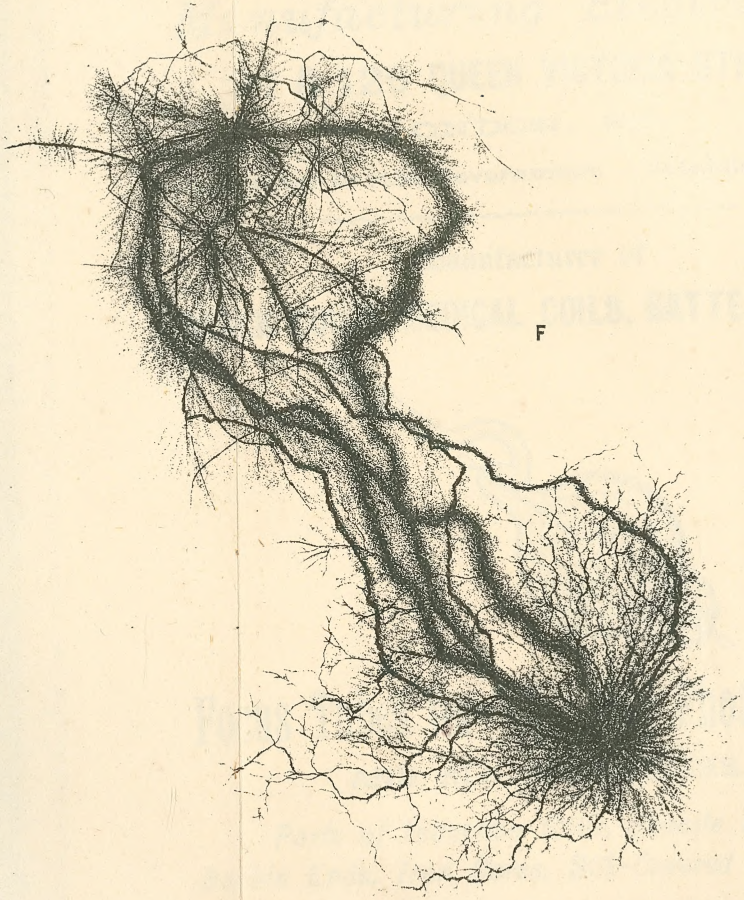
FIGURES PRODUCED BY ELECTRIC DISCHARGES ON PHOTOGRAPHIC PLATES.

See Page 153.

(Frontispiece)



A



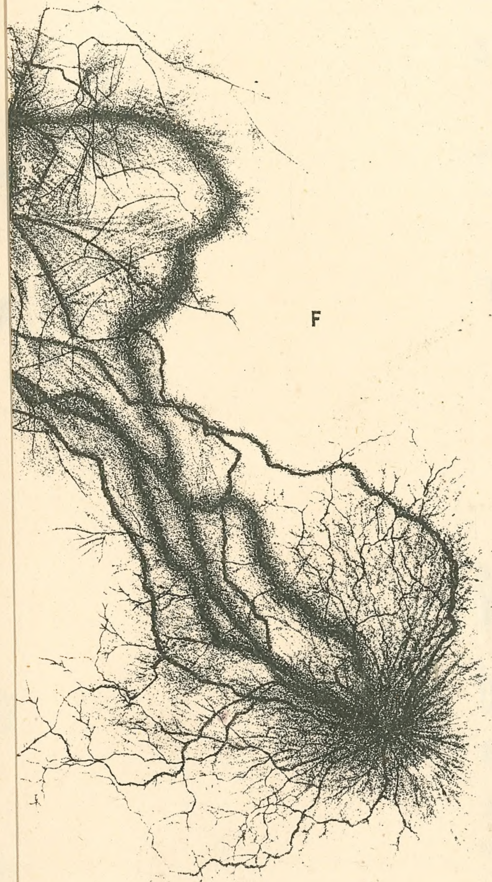
F

B

FIGURES PRODUCED BY ELECTRIC DISCHARGES ON PHOTOGRAPHIC PLATES.

See Page 153.

(Frontispiece)



OTOGRAPHIC PLATES.

See Page 153.

INDUCTION COILS

AND

COIL-MAKING

A TREATISE
ON THE CONSTRUCTION AND WORKING OF SHOCK, MEDICAL AND SPARK COILS

BY

F. C. ALLSOP

AUTHOR OF
'PRACTICAL ELECTRIC-BELL FITTING'; 'TELEPHONES, THEIR CONSTRUCTION AND FITTING'
'PRACTICAL ELECTRIC-LIGHT FITTING'; 'ELECTRIC-BELL CONSTRUCTION,' ETC.

FOURTH EDITION, REPRINTED FROM THE THIRD

WITH 125 ILLUSTRATIONS

London
E. & F. N. SPON, LIMITED, 125 STRAND
New York
SPON & CHAMBERLAIN, 123 LIBERTY STREET
1902

PREFACE.

In compiling this book it has been my aim to produce a practical manual that will prove of service not only to those engaged professionally in the construction and repairing of coils but also to the medical man and amateur coil-maker. I have given, therefore, in addition to dimensions and full details for constructing different kinds of coils, many practical hints and suggestions that I trust will enable medical men and others having the care and working of such instruments under their charge, to keep them in efficient working order with the minimum amount of trouble and expense.

A large portion of the book has already appeared as a series of articles in the 'English Mechanic,' and I have also collected together much interesting and useful information on coil-constructing, gleaned from the last twenty-five years of back volumes of that journal.

F. C. ALLSOP,
Manufacturing Electrician.

97 Queen Victoria Street,
London, E.C.

CONTENTS.

ILLUSTRATIONS.

INDUCTION COILS AND COIL-MAKING.

CHAPTER I.

INDUCTION.

INDUCTION coils may roughly be divided into three different kinds. We have, first, the ordinary "Shocking" Coil, with its comparatively mild effects; second, the Medical Coil, which is more powerful, and has usually an arrangement allowing a primary, secondary, and in many forms a tertiary current to be administered; and, third, the Spark Coil, which is too powerful for shocks or medical use, and intended chiefly for experimenting. All these three kinds of coils—which are very similar, the main difference being chiefly in the proportion of the windings—depend for their action on the inductive effects an alternating or interrupted current circulating in one coil produces in another surrounding it, and before passing on to their construction it will be as well to just glance at the phenomena of magnetism and induction.

The space all round a magnet in which its influence is felt is called the magnetic field of the magnet, and the distribution of this field we are enabled to see by the aid of some iron filings. If we take a bar-magnet, and, laying it in a horizontal position, place on the top of it a piece of sheet glass on which have been sprinkled some fine iron filings, it will be found that on gently tapping the glass the iron filings will arrange themselves somewhat as in Fig. 1. They will collect chiefly round the poles, as shown, and set themselves in definite lines or curves, which spread out and pass from pole to pole. These lines, which vary according to the shape of the magnet, show the direction of the field, and are called "lines of magnetic force"; or, for short, "lines of force." If we further investigate the field of a magnet we find that the lines of force apparently endeavour to pass from pole to pole, and in doing so encounter a certain resistance from the air. This latter point is made evident from the fact that if a piece of iron is placed anywhere in the magnetic field, those lines of force

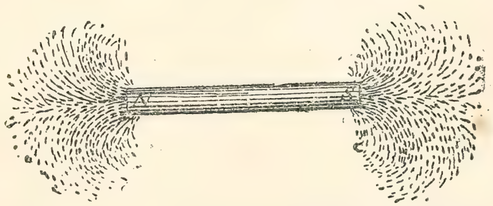
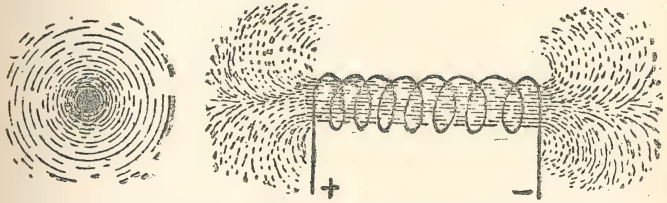


FIG. 1.—IRON FILINGS ROUND POLES OF A MAGNET.

close to—and whose path does not naturally lie through—the iron will be immediately diverted from their course, and pass through the iron in preference, and the lines of force passing through the space occupied by the iron will be much denser than were the iron not there, thus indicating that iron is a better conductor of lines of force, as it were, than air. No other metal or substance will be found to greatly affect the field, which remains practically undisturbed, whether wood, glass, stone, &c., is placed in it, the lines of force passing through them just the same.

There is one thing, however, that will affect and seriously disturb the magnetic field of a magnet. This is a wire carrying an electric current. Electricity and magnetism are

closely allied, and Oersted discovered in 1820 that a wire, no matter its composition, carrying an electric current, possessed certain magnetic properties which ceased the moment the current was stopped. All round a conductor in which a current is flowing, there is in fact a magnetic whirl, and by the aid of our sheet of glass and iron filings, we are enabled to see these lines of force outside the conductor. To do this the glass must have a hole bored in the centre, and be supported in a horizontal position. If now a wire carrying a fairly large electric current be passed through the centre of the glass on which iron filings have previously been sprinkled, the filings will be found to arrange themselves



FIGS. 2, 3.—MAGNETIC WHIRLS ROUND WIRES CARRYING ELECTRIC CURRENTS.

into concentric circles as shown in Fig. 2. Again, if we take a suspended compass needle, and stretch near it a wire carrying an electric current, the direction of the wire being parallel with the needle, it will be found the needle will swing round and set itself at right angles to the wire, the direction in which it swings being governed by the direction in which the current is flowing, and also whether the wire be above or below the needle. If we take a piece of insulated wire and twist it into a coil, we find, on passing a strong current of electricity through it and testing it with the iron filings or compass needle, that the helix presents a field of force as shown in Fig. 3, which is similar to that of the permanent magnet in Fig. 1. On further experimenting with this coil, it will be found that the magnetic effects are greatly intensified if a soft-iron rod is slipped through the centre of helix, as shown in Fig. 4. The iron rod, it will be found, has become magnetised, and exhibits all the phenomena that a permanent magnet of that form does, with, however, this difference, the magnetism only lasts so long as the current is flowing in the helix, and ceases the moment the current ceases. This form of magnet is called an electro-magnet. If, instead of the soft-iron rod, we place in the centre of the helix a hard steel one, we shall find that the steel has also become magnetised, though in a lesser degree, and that on the cessation of the current the steel rod retains most of its magnetism, and has become permanently magnetised. On

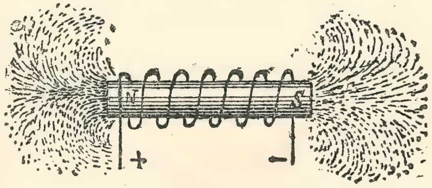


FIG. 4.—ELECTRO-MAGNET.

trying hard cast iron we find the same effects as with the soft iron, but that the cast iron retains some of its magnetism; in fact, the harder the iron the more magnetism it retains. This magnetism that remains in an electro-magnet after the magnetising influence has ceased is called "residual magnetism."

Soft iron, as we have said, loses its magnetism the moment the magnetising influence is withdrawn; steel or hard iron do not; and from this we see that in the construction of electro-magnets soft iron is the best—the softer the better. For this reason the iron core of induction coils is made up of a number of lengths of thoroughly annealed charcoal iron wire, No. 20 or 22 gauge, bound into a bundle, thus producing

an iron core of the softest possible nature, and one that is most rapidly magnetised and demagnetised. If in Fig. 4 we have some means of testing the amount of magnetism in the iron rod, we find that as we increase the current so we increase the magnetism in the rod. We find also that if, instead of increasing the current, we increase the number of turns of wire round the iron rod, we likewise increase the magnetism. In constructing electro-magnets we are accustomed to speak of the "ampère turns" of the magnet—that is the number of turns of wire multiplied by the current in ampères. We can get the same amount of magnetism in a given piece of rod, whether we have a large number of turns of wire and a small current, or a large current and a small number of turns of wire. For instance, 10 turns of thick wire carrying 40 ampères round a piece of iron rod, will give approximately the same magnetism as 100 turns of thinner wire carrying only 4 ampères. We find also that after a certain stage it is of no use to increase the current or wind on any more turns of wire, as the magnetism does not increase, or, if it does, only in a very slight degree. This is because the iron rod has become so saturated with magnetism that it will not take up any more, and any further expenditure of power is simply being wasted. The iron rod is said to be "saturated," and the point at which the iron rod becomes saturated depends on the size and quality of the iron. The softer the iron and the thicker the rod the more magnetism it will take up, as the iron will only admit of a certain number of lines of force per square inch. Cast iron will not admit of so many as wrought, and hard steel still less, so that to get the best results in electro-magnets the iron should be as soft as possible, both because a soft iron core can be the most powerfully magnetised, and will the most rapidly take up and part with its magnetism.

There is another effect produced by a wire carrying an electric current, and that is its inductive action or the "induction" it produces on wires or conductors in its immediate neighbourhood. A wire carrying an electric current that is alternating or pulsating in its character, will be found capable of inducing, under certain conditions, a similar current in any closed circuit within range of its field. The magnetic whirl round a wire, which increases as the current increases, extends, there is not the slightest doubt, very much further than we are able to trace it with iron filings. This is made evident by the fact that the feeble currents in one telephone wire, the existence of which it would be difficult to detect externally, will induce currents in neighbouring wires, some two feet or three feet off, sufficiently powerful to

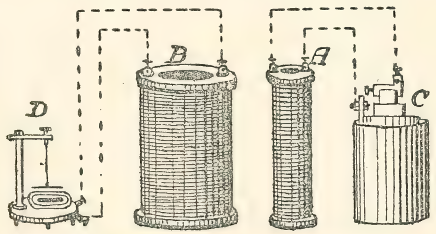


FIG. 5.—APPARATUS FOR OBSERVING THE PHENOMENA OF INDUCTION.

be annoying. The inductive action of one wire carrying an electric current on neighbouring wires can best be observed in the following manner:—Procure a narrow wooden bobbin (A, Fig. 5) six inches long and having a $\frac{1}{4}$-inch hole through the centre, and on this bobbin wind four layers of No. 20 cotton-covered copper wire, fastening the ends of the coil under two terminals at the top, as shown in the figure. Next, get another bobbin (B, Fig. 5) the same length as the former but considerably wider, and having a hole in the centre of sufficient width to allow of the coil A being easily and quickly slipped inside of it. This bobbin wind with about thirty layers of No. 40 double cotton-covered wire, the

different layers being insulated with a wrapping of paraffined paper, and the ends of the wire fastened to two terminals as previously described. Then connect the coil B by two wires to a sensitive galvanometer D, and join two wires to the coil A, so that it can be connected to a powerful battery C, as in the figure. Let us first experiment with the coil B by itself. If we plunge a powerful bar permanent magnet into the centre of this coil we find that the needle of the galvanometer swings sharply to one side, finally returning to its position of rest, and also that on quickly withdrawing the magnet the needle swings to the other side. This shows that a current of electricity was twice momentarily generated in the coil, first at inserting and again on withdrawing the magnet, the two currents being in different directions. This is the phenomenon of induction, and to produce these induced currents in the coil we must have a movement between the coil and the magnet. The coil must be moved so as to cut lines of force or alter the number passing through it, and the currents are momentary, lasting only while the movement continues. The mere leaving of the magnet in the coil will have no effect, as will be seen by the needle of the galvanometer going gradually back to its position of rest. We saw from Fig. 4 that if we send a current through a helix we get a magnetic field and effects similar to a bar magnet. By plunging a bar magnet into the coil B we send lines of force through it somewhat similarly distributed to those produced by a current flowing through the coil itself, so that we might almost have anticipated that if we create the magnetic whirl around the coils of wire we shall get a momentary current in the helix. Let us now lay aside the permanent magnet, join up the coil A to a battery, and insert a soft iron rod in the centre. We have now an electro-magnet with a field of force similar to the permanent one with which we have just been experimenting, and therefore we naturally infer that if we plunge the coil A into the coil B we shall get the same effects as we did with the permanent magnet. This, on experimenting, will be found to be the case; we get a momentary current on plunging the coil A into the coil B, and again a momentary one in the reverse direction on withdrawing it. We will now go a step further: if plunging the electro-magnet A into the coil B induces currents, then making and breaking the battery connection with the coil A, and thus rapidly magnetising and demagnetising the coil A inside the coil B should produce the same results, as this is tantamount to plunging in the magnet and withdrawing it. This, on making the experiment, will again be found to be the case, and in the two coils we have the main parts of an induction coil, the primary coil A, through which circulates the current from a battery, and the secondary coil B, in which we get the induced currents. It needs only, therefore, to insert an automatic make-and-break in the primary or battery circuit, and we shall then get a quick succession of currents in the primary coil which induce others in the secondary coil, these latter being of considerably higher tension and of a rapidly alternating character.

Fig. 6 shows how the two circuits of an induction coil are arranged, P and P^1 being the ends of the primary and S and S^1 the ends of the secondary. The primary winding is shown darker than the secondary.

The same effects would be produced by the coil A even if it had no iron rod in it, but of a very much feebler character. If we further experiment with the two coils, and compare the effects produced by inserting the coil A first slowly and then quickly into the coil B, and also with a hard steel and then with a soft iron rod in the centre of the coil A, we shall find that the more rapid the motion, and also the softer the iron core, the more powerful the effects. By employing a bundle of soft iron wires for the centre of the primary coil of an

induction coil, we have a core that will not only absorb the most magnetism but also allow itself to be the most rapidly magnetised and demagnetised.

The current in the secondary coil B makes itself manifest in other ways than by its effect on the needle of the galvanometer, the most prominent being, first, a peculiar sensation (called an electric shock) in the wrists and up the arms when the ends of the coil are held one in each hand, and, second, a rapid succession of sparks between the ends of the coil if brought near together. On seeing these large sparks taking place between the ends of the secondary coil while those in the primary are comparatively small, beginners are apt to get

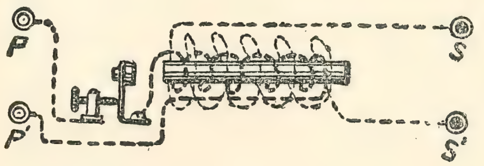


FIG. 6.—CIRCUITS OF COIL WITH BOTH PRIMARY AND SECONDARY.

a wrong idea of the action of a spark coil, concluding that the coil generates more electricity than is supplied by the battery. This, however, is entirely wrong, for, as a matter of fact, the electric energy in the secondary coil is less than that in the primary, and the large spark arises from a higher potential of the secondary current, which thus enables it to leap across gaps in the circuit. Even were the winding of the primary and secondary coils exactly similar, the induced current would still have a higher potential than the inducing current; but as in spark coils the secondary consists of thousands of turns of very fine wire, the current generated in it is naturally of a very high potential.

Small shock coils are sometimes made, however, with a primary winding *only*, as in Fig. 7, and here the shocks arise from the battery current in the coil inducing, at the moment of cessation, a momentary current of a considerably higher potential than the battery current in the coil itself. This is called

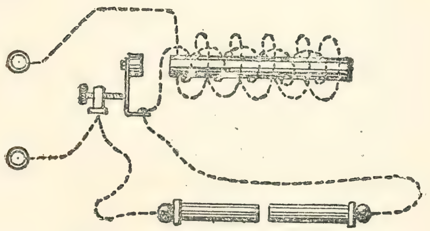


FIG. 7.—PRIMARY SHOCK COIL.

the "extra current," and arises from the "self-induction" of the coil, and in constructing a primary coil our aim is to use a bobbin, the self-induction of which is as high as possible.

If we turn again to our battery and experimental coils, as shown in Fig. 5, we find that when we join the two wires from the battery and pull them apart again we get a small spark at the moment of breaking contact. Connect, now, one wire from the battery to one terminal of the coil A (the iron core being in the centre), and momentarily touch the other wire on the other terminal, and it will be seen that the spark we now get at the moment of opening the circuit is very much brighter and longer. This arises from the fact that the current in the coil has, at the moment of breaking the circuit, induced another in the coil of much higher potential, thus enabling it to jump across a much wider gap. It is not that the coil has augmented the original battery current, as this must necessarily be less (owing to the resistance of the coil) than when we short-circuited the battery. Moreover, when we connect into the circuit any old magnet coils we may have by us, we find that as we connect more in, so we increase the spark at break, and this is because we have

raised the self-inductive capacity of the circuit. If we take the two wires at the point where we have been breaking the circuit, and twist each end of the wire round a separate piece of metal, we shall find that if we hold one of these pieces of metal in each hand, touch them together, and then pull them apart again, we feel a smart shock, owing to the induced current passing through the somewhat lower resistance of the body in preference to sparking across between the two pieces of metal through the air.

It is in this manner a shock is obtained from a primary coil, the two handles being connected (see Fig. 7) one each side of the make-and-break. It is possible to wind wire into a helix in such a manner that all self-induction in the helix is practically eliminated, as is done in the case of resistance coils for testing purposes, where the wire is coiled on the bobbin so that the inductive effect of the one wire running from the one terminal is neutralised by that in the one running back to the other.

CHAPTER II.

HINTS ON THE CONSTRUCTION OF COILS GENERALLY.

BEFORE we can proceed with the construction of any coil, the correct sizes and amounts of primary and secondary windings necessary to produce the shock or length of spark desired must be worked out, in order that the proper size of bobbin to employ can be determined. The bobbin is the first part that should be constructed, and the right dimensions for this having been determined the proper proportions for the other parts of the coil can at once be decided upon. As soon as the size of bobbin is ascertained a rough sketch to scale should be made, showing in plan and elevation the complete coil, the six principal parts of which are enumerated below in the order in which they should be constructed.

These are:—

1st. The bobbin.
2nd. Iron core of bobbin.
3rd. Primary winding.
4th. Secondary winding.
5th. Contact-breaker and terminals.
6th. Base or stand.

These comprise the essential parts of every coil, though to the list must occasionally be added the tertiary winding with which some medical coils are provided, and the condenser used with spark coils.

Determining Size of Primary and Secondary Windings.

The primary winding, as was pointed out in Chapter I., is the wire wound directly on the iron core, and is comprised in the primary circuit, consisting also of the battery and contact-breaker; while the secondary is wound outside the primary, and has electric currents generated in it by induction from the primary. The low tension current in the primary is in the secondary converted into one of high potential, and as we almost always want, in an induction coil, to produce currents of very high potential, the primary is wound with a few turns of thick wire and the secondary with a large number of turns of very fine wire. We have in the primary circuit a somewhat large current of low electro-motive force, and our object as regards the primary winding is, therefore, to provide such a path round the iron core as will make most use of this current in magnetising it.

It is this consideration almost wholly that governs the winding of the primary in the spark coils, though with medical coils giving a primary shock as well as a secondary the case is somewhat different.

Taking first the case of spark coils, however, our object is to get a primary winding that will give the most intense magnetism to the core, occupy a minimum of space, and be least troubled with self-induction.

Self-induction, as we saw in Chapter I., is the extra current induced by the primary current in the primary winding itself, and its chief effect is to momentarily retard the filling and emptying (if we may so call it) of the primary coil. We saw also that the self-induction increased with the number of turns of wire, so it is evident that if we wish to reduce the self-induction to a minimum there must be as few turns as possible on the primary consistent with getting the requisite magnetism. In spark coils it is usual, therefore, never to put on more than two layers of primary, but to increase the gauge of the wire and the size of the cells as the size and sparking power of the coil is increased.

Thus, for spark coils giving $\frac{1}{8}$ to $\frac{1}{4}$ inch spark, No. 24 and 22 (B.W.G.) wire is usually employed, No. 20 for $\frac{1}{2}$-inch spark, No. 18 for $\frac{3}{4}$ to 1-inch spark, No. 16 for sparks from 2 to 3 inches, No. 14 for 6 to 8-inch spark, and No. 12 for 8 to 12 inches.

With medical coils, however, giving primary shocks as well as secondary, it is usual to put on from four to six layers of No. 24, 22 or 20, according to the dimensions of the coil. Since the primary shock arises from the extra current in the primary on interrupting the circuit, two layers would not be sufficient, so more are put on, and the effects of self-induction on the working of the coil are of little moment in this case, as we do not aim at a very high efficiency from the secondary, the secondary shock being always quite strong enough for most people.

The rule, therefore, for the amount of wire to be put on the primary winding is simple enough—two to three layers for spark coils, four to six layers of smaller gauge for medical coils—and once the gauge of wire is determined it is an easy matter to find the depth of space it will occupy on the bobbin.

The primary of a spark coil will have, of course, a very much lower resistance than a medical coil of the same size; but then the battery employed with a spark coil is of a much more powerful kind, and capable of sending a large current through this low resistance.

The secondary is wound with a large number of turns of very fine wire, No. 36, 38 or 40 for spark coils, and No. 34 or 36 for medical coils. In spark coils the object is to get as high electro-motive force or pressure as possible, as upon the E.M.F. depends the sparking distance or size of spark the coil will give. Every additional turn on the secondary increases the E.M.F., and since the finer the wire the more turns we can get on the coil, a fine wire is always used—No. 40 or 38 for the coils up to 6-inch spark, and No. 36 for larger ones. If a thicker wire is used the spark will not be so long but it will be brighter and thicker, and thus if a good thick spark is desired No. 36 should be employed. The inner layers, of course, contribute more to the effects than the outer ones, being nearer the inducing current and thus more strongly acted upon. Each succeeding layer, therefore, although it must necessarily contain more wire than the preceding ones, adds less and less to the effects, till, after a certain thickness has been obtained, it is useless to wind on more layers. In actual practice, of course, this point is never reached with induction coils, as if we want to put a large amount of wire on the secondary we lengthen the bobbin, so that the last layer is well within the field of induction.

For medical coils a thicker wire is used for the secondary, firstly, because we do not want anything like such powerful effects, and, secondly, because the shock produced by a thick secondary winding is less stinging and more pleasant than a thin one. No. 36 is the size usually employed for small medical coils, and No. 34 for larger ones. Of course, if a medical coil is wanted that will go in a very small space No. 38 or 40 can be employed for the secondary, but then a very small quantity must be used.

In specifying the amount of secondary on a coil it is customary to speak of it by weight, so many ounces or pounds of No. 38, &c.—ounces in the case of medical coils, but it soon runs into pounds with large spark coils. A rough rule is to allow about $\frac{3}{4}$ lb. No. 40 and 1 lb. No. 38 or 36 on the secondary for every inch of spark required, but so much depends, in a spark coil, on the skill of the constructor that no really definite rule can be given. The dimensions and quantities of wire for several medical and spark coils are given in Chapters III. and V., and are taken in every instance from coils actually constructed.

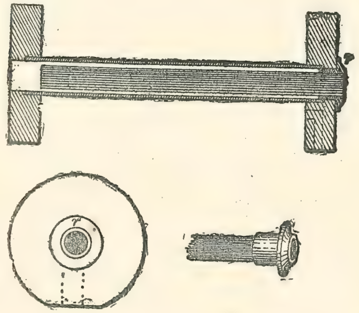
TABLE OF RESISTANCES, &c., OF COPPER WIRE.

B. W. G.	Decimal of an inch.	Equivalent in m/m.	Yards to the lb. Bare.	Resistance Bare Wire. Per lb. Ohms.	Resistance Bare Wire. Per Mile Ohms.	Price per lb., Silk Covered. Single. £ s. d.	Price per lb., Silk Covered. Double. £ s. d.	Price per lb., Cotton Covered. Single. £ s. d.	Price per lb., Cotton Covered. Double. £ s. d.
8	·165	4·19	4·05	0·00475	2·063	0 3 0	0 4 3	0 2 0	0 2 3
10	·134	3·40	6·14	0·0109	3·128	0 3 0	0 4 6	0 2 0	0 2 3
12	·109	2·77	9·28	0·0249	4·727	0 3 3	0 4 6	0 2 0	0 2 3
14	·083	2·11	16	0·0741	8·153	0 3 3	0 4 6	0 2 0	0 2 3
16	·065	1·65	26·1	0·1971	13·29	0 3 3	0 4 6	0 2 0	0 2 3
18	·048	1·22	47·9	0·6629	24·38	0 3 6	0 5 6	0 2 0	0 2 3
20	·036	·914	85·1	2·095	43·34	0 3 9	0 6 3	0 2 6	0 2 9
22	·029	·736	131·1	4·976	66·79	0 4 0	0 6 9	0 2 8	0 3 0
24	·025	·635	176·4	9·009	89·86	0 4 3	0 7 6	0 3 0	0 3 6
26	·019	·482	305·5	27·01	155·6	0 4 6	0 7 9	0 3 3	0 3 9
28	·016	·406	430·8	53·72	219·4	0 5 3	0 8 6	0 3 9	0 4 3
30	·014	·355	562·7	90·61	286·6	0 6 5	0 10 6	0 4 0	0 4 6
32	·012	·305	765·9	169·7	390·1	0 6 9	0 12 0	0 4 6	0 5 3
34	·010	·254	1102	351·9	561·7	0 8 0	0 13 6	0 5 0	..
35	·0087	·221	1457	614·3	742·0	0 9 6	0 15 0	0 6 0	..
36	·0079	·200	1767	903·5	900·0	0 10 6	0 17 0	0 6 9	..
38	·0066	·167	2532	1855	1289	0 13 6	1 2 3	..	..
40	·0058	·147	3278	3110	1670	0 18 9	1 7 9	..	..
..	·005	·127	4411	5631	2247	1 4 0	1 17 6	..	..
..	·004	·101	6894	13753	3511	1 7 9	2 5 0	..	..
..	·003	·0761	12256	43471	6242	2 2 9	3 7 6	..	..
..	·002	·0508	27586	220220	14050	3 11 3	6 0 0	..	..

On page 16 is given a table of the resistance per lb., length of feet to ohm, &c., of the different sizes of copper wires, which will be found of great use in working out the proportions for the primary and secondary of coils.

Bobbins.

These should be either of wood or ebonite, and the ends or cheeks may be round, square, or any special fancy shape

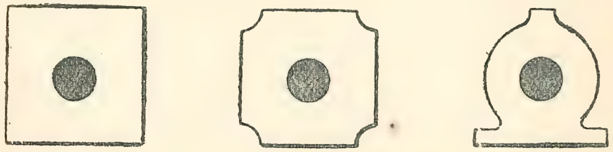


FIGS. 8, 9, 10.—BOBBIN WITH IRON CORE.

desired. The form of bobbin generally employed, however, for medical coils and small spark coils has round ends, as shown in Figs. 8, 9, and 10, Fig. 8 being a section through the bobbin showing the iron core, and Fig. 9 a view from the contact-breaker end. Fig. 10 shows the end of the iron core fitted with a brass bush, about which we shall treat later on. The bobbin is intended for a medical coil, and has, therefore, it will be seen, a space between the iron core and inner surface of the tube of the bobbin for the brass regulating tube.

Next to the round end, the square end, as shown in Fig. 11, is a favourite one for spark coils, as is also the form of end shown in Fig. 12, which has its rectangular appearance removed by grooving off the corners. Fig. 13 is a form of end frequently employed in medical coils where a separate contact-breaker is used, the upright piece at the top being required for carrying the brass arm of the contact-breaker. An enlarged view of this and other forms of bobbin ends will be found in the illustrations of the complete coils in Chapters III. and V.

Beech and boxwood ebonised, mahogany and walnut, are the favourite woods out of which bobbin ends are made, though ebonite is largely used and has the advantage in being a better insulator. In constructing the bobbin there are three methods that may be employed: 1st, the bobbin



FIGS. 11, 12, 13.—VARIOUS FORMS OF BOBBIN ENDS.

may be turned up complete out of a solid block of wood; 2nd, the ends may be fixed direct on to the iron core, and, 3rd, a paper tube may be made and the bobbin ends firmly fixed on to it by glue. The first method is only admissible for very small coils, owing to the difficulty of turning down the tube of the bobbin to the required thinness without breaking it.

The block of wood out of which the bobbin is going to be turned should be roughly turned to size, after which the centre hole is bored, a metal rod (of such size as will only give just sufficient grip for turning) driven into it, and the bobbin finished on this.

Sharp tools are requisite, and great care must be exercised in turning bobbins of this kind, as the body of the

bobbin must be turned as thin as possible consistent with safety.

In constructing a bobbin by the second method, first turn up two bobbin cheeks of the required dimensions and ebonise, or if made in mahogany or walnut, polish them. Now cut off the lengths of the iron wire, and work them into a neat bundle by sliding one of the bobbin cheeks on each end. Next procure some thickish cartridge paper, and cut two or three strips $2\frac{1}{2}$ in. wide, which strips must afterwards be rolled round the iron core, fastening each layer with some thin glue till a tube of about $\frac{1}{32}$nd of an inch in thickness is formed on it. The bobbin cheeks can now be slipped off, the inside of the holes glued, the cheeks slipped back on to the core, and the whole firmly fixed in a clamp till perfectly dry. The paper tube must, of course, be rolled on the iron core at the proper place, which can be ascertained by measurement, and the cheeks of the bobbin made to butt against the ends of the tube.

For spark coils it is advisable to use melted paraffin wax to fasten the different layers together, and when finished the inside of the bobbin must be well basted with the wax.

Perhaps the best bobbin can be made by the third method, to do which proceed thus:—Having turned up or cut out the two ends of the desired size and shape, bore a hole in the centre of each, which hole is somewhat enlarged on the inner sides, as shown in Figs. 8 and 9. A paper tube is next prepared by rolling cartridge-paper smeared with thin glue round a ruler (the ruler having been previously rubbed with soap to prevent its sticking), which is afterwards withdrawn, and this tube, when perfectly dry, has the wooden ends affixed to it, this being done by smearing the ends of the tube with glue and inserting them into the enlarged part of the holes, leaving the bobbin so formed to harden in a clamp if possible. This form of bobbin is best suited for shock and medical coils having the tube method of regulation.

For large spark coils it is advisable to employ ebonite ends and separate primary and secondary by a thin ebonite tube. The bobbin ends must first be prepared as before described, except that the hole is of the same size all along in order to allow the ebonite tube to pass right through and project beyond the bobbin cheeks. For the tube of the bobbin either an ebonite tube of the required diameter can be procured or one can be constructed by warming thin sheets of ebonite and bending round a ruler, the joins being fastened off with shellac. Two or three layers are put on until a tube of the required thickness is formed, care being taken to see that the joins of the several layers are made at different sides of the tube.

The size of the bobbin is determined chiefly by the amount of wire there is to be put on, and the quantity being known the amount of space it will occupy with the layer of paper and other insulation must roughly be calculated out. It is advisable to leave a good margin, as so many things may occur in winding on the wire that it is not possible to calculate exactly, while, moreover, a little space to spare after all the wire is on is not objectionable, as it can be filled in with a layer of string or wrapping of velvet or sheet ebonite to prevent mechanical injury and improve the appearance.

As to the thickness of the bobbin cheeks and tube, the former, if of ebonite, should be from $\frac{1}{4}$ to $\frac{1}{2}$, if of wood $\frac{1}{2}$ to $\frac{3}{4}$ inch, while the latter will vary from $\frac{1}{16}$ to $\frac{1}{4}$, according to the size of the coil and the length of spark it is intended to give.

Iron Cores.

We saw in Chapter I. what an important part the iron rod in the centre of the primary coil played, and how necessary it was that this core should be of the best and softest iron. The best cores are made of a bundle of No. 22 or 20 best charcoal iron wire thoroughly well annealed, and as this wire varies much in quality, the reader is advised to use that of the best makers only. It can be purchased either in bundles of required lengths, or in one length on a coil, but if bought in this latter form each length, after being cut off, requires to be carefully straightened. The length of the iron core should be such that it projects about a quarter-inch at each end of the bobbin for small spark coils, but at one end only if for a medical coil. The lengths of wire, after being cut off, are slipped into the centre of the bobbin (a little patience and care being requisite in getting in the last one or two), so as to form a good solid core. In medical coils having a regulating brass tube sliding over the iron, the core must be made into a bundle so as to leave a small air-space between the outside of the iron core and the inside of the bobbin-hole for the tube to work in. This form of core is shown fixed in its place inside the bobbin in Figs. 8 and 9, the core being fitted with a brass bush *r*, as in Fig. 10, which bush is forced into the bobbin, so that the iron core touches the bobbin nowhere but at this point. The core is best made into a bundle for this purpose as follows:—Slip the different lengths, after being cut off, into a metal tube, the inside diameter of which is the exact size you wish the core to be. When the tube is full slide out one end of the bundle of wires; bind it firmly with some fine wire, and then dip the end for half an inch into some melted solder, using spirits of salt as a flux. Let it cool, smooth off with a file, and then proceed to treat the other end in the same manner. When quite cool it can be forced into the brass bush *r*, and fitted into the bobbin. The brass bush, of course, goes into the contact-breaker end, and besides its use in holding the core, also gives a better finish to that end of the bobbin. With spark coils it is preferable not to make the core into a bundle, as this process somewhat hardens the wire, but to force as many lengths of wire into the centre of the bobbin as possible.

Some Continental manufacturers employ an iron core consisting of thin sheet iron rolled up into a tube of several layers, as shown in Fig. 15, but this method is not so efficient as the bundle of iron wires, although for small medical coils, if the centre of the tube is filled with iron wire, the difference should be inappreciable.

In medical coils, where the regulation is effected by sliding in and out the iron core, a solid core is sometimes employed, on which is marked a scale to show the distance it is drawn out. A better method, however, where a movable core is required, is to roll up a stout paper tube that will slide easily into the centre of the bobbin, fill the centre with lengths of iron wire, and after fitting a small wood knob or handle at one end, plug up the other with a short cork, cutting off any that projects. In such a manner a very neat core can be made, the surface of which can be covered with coloured paper and pasted with a printed scale.

The regulating tube of a medical coil is a thin brass one, of such diameter that it will just slide over the iron core. It is fitted at the outside ends with a handle or knob for operating it, this handle being of ebony or ebonised box-wood, and affixed to the tube either by some cementing compound, or what is perhaps better, by making the part of the knob entering the tube a good fit, and then centre-punching the tube on either side. The tube should slide in and out of the bobbin easily and steadily, but without unnecessary play, the tube bearing on the hole in the centre of the bobbin, and leaving ample clearance between the core and the inner surface of the tube. The easy working of the regulating tube is a most important point in all medical coils, as it allows the increase and decrease in the strength of the shock to be made very gradually, and not in a jerky or sudden manner, as must necessarily be the case where the tube fits somewhat tightly.

Winding the Primary.

Before passing on to the winding, we will first describe the construction of a "coil-winder," a piece of apparatus which will be found almost indispensable should the operator not be possessed of a lathe, while even when this is the case, the employment of a coil-winder will often be found more suitable and convenient. A convenient form of coil-winder used by the writer for winding coils is shown in Fig. 14. The apparatus consists of a stout wood base *m*, to which are

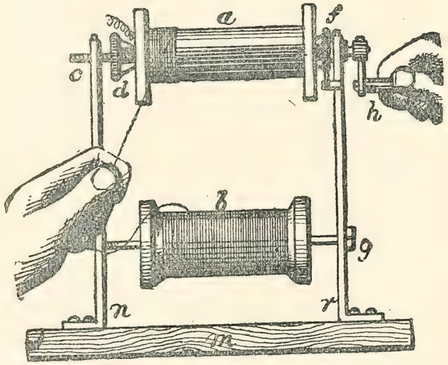


FIG. 14.—A COIL-WINDER.

fastened the two standards *n* and *r* of $\frac{1}{4}$-in. by 1-in. iron rod. At the top of each of these standards a hole is drilled to carry the iron spindle *c*, which can be rotated by the handle *h*. At the right-hand end of this spindle is the fixed coned stop *f*, while at the other end is the adjustable one *d*, running on the threaded portion of the spindle. This adjustable stop consists, it will be seen, of a milled metal disc secured to the end of a piece of brass tube, which is drilled and tapped to run on the spindle *c*. Three pieces of triangular sheet-brass are soldered on to the tube and disc at equal distances, as shown, thus giving the stops a tapered form, so that, owing to the one being adjustable to the other, almost any size and form of bobbin can be readily inserted and securely clamped in the winder. The spindle can be removed from the upright standards *n* and *r*, by turning round the catches at the top, which then allow the spindle and coil to be lifted out bodily. The spindle *g*, at the bottom, carries the reel of wire *b*, with which the coil is going to be wound, the reel being removable by turning the nut on the right-hand end of the bolt *g*, which causes it to unscrew out of the upright *n*. A small ratchet can be arranged to work on the stop *f* if desired, so as to prevent the coil unwinding when the handle is released. To use the winder the handle *h* is turned with the right hand, while the wire is fed on evenly, regularly, and with moderate pressure with the left, as shown in the figure.

Previous to commencing to wind the bobbin it should first be carefully looked over, to see that there are no weak points either in its construction or in the insulation between the iron core and the space in which we are going to wind the primary. Having satisfied ourselves that the bobbin is properly made, some hot paraffin wax should be prepared, and the inside of the bobbin thoroughly basted with it and allowed to cool. The paraffin wax, by the way, will constantly be required during the winding, so it should be kept close at hand in a suitable contrivance that will keep it always at the proper temperature. In purchasing paraffin wax care should be taken to get only the very highly refined, as some of the qualities of wax that are frequently offered are very inferior as to insulating properties. The wax should be white, and clear from any impurities. It is best heated in a small metal bowl with spirit-lamp underneath, great care being taken, however, that it does not get too hot and burn. It should be carefully kept away from all

metal filings, both when melted or in a solid state, as if only one or two filings get in they are liable to be picked by the brush when applying the wax, and drop into a most important place and be the cause of a subsequent breakdown in the insulation of the coil.

The wire employed for the primary winding should be the best high-conductivity copper wire well insulated with silk, or in some cases cotton may be used. For spark coils the use of silk only is advised, as silk is by far the best insulator, and considering the tension of the sparks and their constant tendency to pick out any weak point in the insulation, it is most important no efforts be spared to make the insulation as perfect as possible. For medical coils, however, the tension is not very great, and cotton-covered wires will be quite sufficient, and are, moreover, considerably cheaper, especially when we come to take into account the fact that double the length of primary is usually required for medical coils.

The two ends of the primary winding are usually brought out at the contact-breaker end of the bobbin. In bringing out these ends, there are two methods that may be employed; first, holes can be drilled right through the bobbin cheeks, and the wire run down outside the cheek to the base; or second (and this has the better appearance), holes are drilled from the inside of the bobbin in an oblique direction—somewhat as shown by the dotted lines in Figs. 8 and 9—so that the ends of the wire come out, not on the outside face of the bobbin cheek, but on the bottom part of the rim where it touches the base. Thus the ends of the wire pass directly from the inside of the bobbin to the underneath side of the base, and are not visible, while, moreover, the wires being embedded in the wood cheek of the bobbin are quite prevented from in any way coming into contact with either the secondary or tertiary windings.

The holes having been drilled in the correct places, the wire (which should be purchased on a reel) must be arranged so that it will pay out properly. If the bobbin is going to be wound in a coil-winder, the reel will merely have to be slipped on the bottom bar (see Fig. 14) and it will run out freely, but if it is intended to wind the primary by hand, as is frequently done, a stout knitting needle can be driven into the bench and the reel slipped over this. The end of the wire must be passed through one of the holes in the bobbin cheek, leaving a tail of about 8 inches, which must be temporarily twisted up into a spiral on a pencil to avoid its getting in the way, and the wire is then wound right along the bobbin and back again, thus making two layers, the finishing end being passed through the second hole and finished off into a spiral like the first. The latter end is known as the outside end and the former as the inside one. For medical coils, of course, four or six layers will be required, but still the outside end will finish at the same end as the inside, only a little higher up the cheek. It is immaterial, as regards the action of the coil, in which direction the primary is wound; but it will be found more convenient in winding if the bobbin is so turned that the wire feeds on to the top part of the coil, as shown in Fig. 14. The wire must be wound on carefully and evenly, and when the whole of the layers are put on they must be well served with paraffin wax. When the winding of the primary is quite finished, it should be tested by connecting up to a cell, and noting that the core is well magnetised.

Winding the Secondary.

Before winding the secondary, two or three layers of good note-paper that has been previously well soaked in paraffin wax must be carefully laid on over the primary, care being taken to see that the outside wrapping when finished presents a firm, level surface for the first layer of the

secondary. If the secondary winding is started with a good level surface, it is comparatively easy to maintain even and regular layers throughout; but commence with a bad surface, and it will be found that each succeeding layer becomes more and more rough and irregular than the one beneath it. For spark coils, as there is a certain amount of danger of the secondary sparking across at both ends into the primary winding or iron core, special care should be taken with this insulation between the primary and secondary, making it somewhat thicker at the ends than in the centre. It is customary in this country to use, for the secondary winding, the very best silk-covered copper wire; but in most foreign coils a method of winding is employed, which we shall presently describe, in which naked copper, or, in the cheaper coils, even naked iron wire, is used.

The wire for the secondary must be of good quality, and as free from joins as possible. Of course, in this fine wire there always will be a certain amount of joins, as it is no easy thing to draw a mile or so without a break; but such joins must be carefully inspected to see that they are properly made and well insulated. Frequently the wire drawers merely tie the ends together, and when this is found to be the case such ties must be carefully joined, soldered, and insulated by wrappings of paraffined silk, a twist-joint being made and care being taken to see that when insulated it is not too bulky. Such joins only become apparent during the process of winding, being felt as they pass through the fingers; but they must be carefully looked out for, as well as any insufficiently insulated places, which will be at once detected by the bright gleam of the copper. The two ends of the secondary are brought out at the opposite end to the primary ends, small holes being drilled in the cheeks of the bobbin. It will be found best, in order to prevent the annoying occurrence of the inside end breaking off, and consequent rewinding of the coil, to join two more tails of wire to the commencement of the winding and bring the three ends out. Thus, if one breaks off there are still two others, or the three wires may be twisted up into a stranded one. The secondary coil is wound on in the same direction as the primary, the wire being carefully guided on evenly, which is, of course, somewhat more difficult than with the primary. The hand feeding the wire on to the coil should be held some 10 inches or 12 inches away, and the point from which it is fed kept slightly behind the point where it is winding on to the coil, in order to cause each succeeding turn to lie close to the preceding one, the coil being steadily rotated by the right hand. When one layer is finished it should first be thoroughly basted with the melted paraffin wax, and then have a layer of paraffined note-paper, slightly wider than the space between the two cheeks of the coil, wrapped round, on which the second layer is wound, and so on, until all the layers are completed. In winding the secondary coil, care should be taken not to take the different layers right up to the cheeks of the bobbin, as the tension between the layers is highest at the ends, and thus if the layers are continued right up to the cheeks, the insulation of the secondary is liable to break down.

The foreign method of winding induction coils is shown in Fig. 15, which shows one end of the coil partly in section and partly in elevation. The bobbin cheek, paper tube, primary and secondary windings are in section, while the iron core and part of the primary winding are shown in elevation. Only two layers of the primary are shown, and the size of the secondary wire much enlarged to make the illustration clearer. The iron core consists of a piece of thin sheet iron rolled into a tube as previously described. The tube forming the body of the bobbin is of paper, fastened into the wood cheeks in the manner shown, and the primary (silk-covered copper wire) is wound directly on to

this paper tube. After the primary is wound, a few layers of paper are put on, and the winding of the secondary commenced. For this, naked copper wire of No. 36 gauge is used, and this is so wound on that each turn is separated from its neighbours by an air-space equal to the thickness of the wire. When the one layer is finished, a wrapping or two of paper is put on, and the winding of the other layer commenced, layer after layer being so put on until the coil is finished. The writer has not had much experience in this method of winding, but he believes it to be performed in a special automatic machine, though it is possible to do it in a

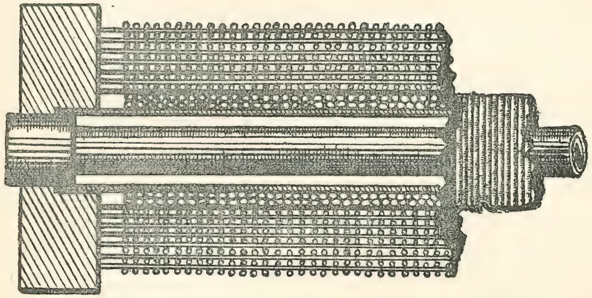


FIG. 15.—CONTINENTAL METHOD OF WINDING COILS.

screw-cutting lathe, the change wheels of which are arranged for a very fine thread, and a special wire-guide fixed in the rest. Apparently the secondary is wound by itself, and afterwards slipped over the primary, as on taking such coils to pieces it will be found that the secondary can be comparatively easily slipped off the primary, while it is not possible to separate the different layers of the secondary. The wire is wound on very evenly and under considerable tension, as it is not easy, even by drawing the point of a knife along a layer, to cause the adjacent turns to touch one another, and the secondary winding by itself forms a tube so hard that it is not possible to flatten it by squeezing it with both hands. The paper used for insulating the different layers is not saturated with any insulating substance, and thus the insulation of the coil, although satisfactory, is not, of course, equal to the English method, where covered wire and paraffined layers are employed. The outside of the coil is covered with a layer of some dark-coloured velvet, which is affixed to the outside layer by a little thin glue. In the old form of the hand electric gas-lighters, in which small spark coils were employed, giving a $\frac{1}{8}$-inch to $\frac{3}{16}$-inch spark, naked iron wire was used, wound as described above, but each layer—and subsequently, on completion, the whole coil—was thoroughly impregnated with paraffin wax, which filled up the interstices of the layers.

This method of winding medical coils necessarily makes them of larger size than the English-made ones of similar power; but it is cheap where a quantity are produced at a time and satisfactory for spark coils if plenty of paraffin wax is used. The English method of construction is, of course, more durable, and gives a better insulation.

Contact-breakers.

The contact-breaker, or interrupter as it is also frequently called, is an arrangement worked either by the magnetism of the iron core of the bobbin, by a separate magnet, or sometimes, in very large spark coils, by hand. Its object, as its name implies, is to interrupt or break the circuit in order to produce the induction between the two windings.

Too little attention is frequently paid in constructing induction coils to the contact-breaker, a part of the coil that is able to influence to a large extent the character of the shock obtained. Of course, given a well-designed and constructed coil, almost any form of contact-breaker will *work* with it; but to get the best results from a coil that has

been designed to give powerful, yet not unpleasant, shocks, the contact-breaker must not be overlooked. Its size, shape, and even the position of the different parts will be found to affect the nature of the shocks. In a good contact-breaker for a medical coil the interruptions should be even and regular, and vary only as the contact-screw is adjusted. An intermittent, or a contact-breaker that is spasmodic in its action, is very objectionable.

Putting aside the hand contact-breaker, which is only used for very large spark coils, there are three kinds of contact-breakers in general use: 1st, contact-breakers worked

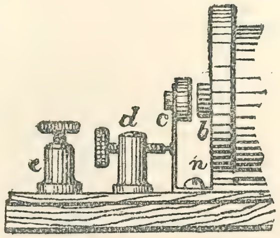


FIG. 16.—VERTICAL CONTACT-BREAKER.

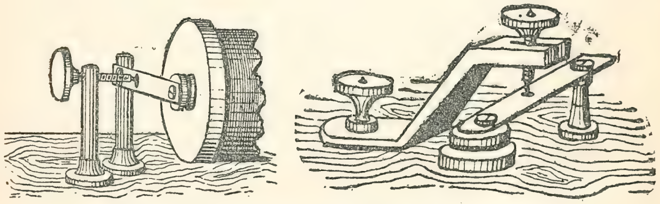
by the coil itself; 2nd, separate contact-breakers; and 3rd, variable contact-breakers, in which the rapidity of the interruptions can be varied from very slow to very fast.

A simple contact-breaker of the first kind, suitable for very small medical or spark coils, is shown in Fig. 16. It consists of the upright spring *c*, carrying at the top the soft-iron hammer head, and behind it is fixed an ordinary contact pillar and screw *d*, such as is used for electric bells. The bottom of the spring is bent at right angles and fixed to the base by the screw *n*.

The most common form of contact for small and medium size medical and spark coils is shown in Fig. 17.

The contact-spring it will be seen is in a horizontal position, and fixed on a separate pillar, close to which is the pillar carrying the contact-screw. On the end of the spring is the soft-iron hammer head, and the other is slotted and fixed, by means of a screw, to the upright pillar, so that the position occupied by the hammer head in front of the core can be adjusted horizontally. The pillars are secured to the wood base by screws passed up from below.

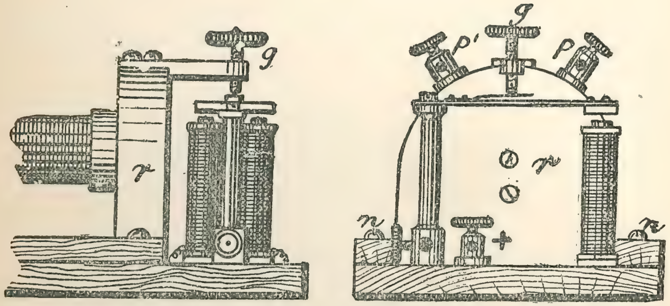
Fig. 18 shows a form of contact-breaker employed in portable sets when the coil is in a vertical position, and the iron core is fixed. The iron core projects up for a half-inch



FIGS. 17, 18.—HORIZONTAL CONTACT-BREAKERS.

through the wood base, and the hammer, fixed on the end of the thin contact-spring, works above it. The contact-spring is carried by a small contact-pillar, seen on the extreme right of the figure. The contact-screw is carried by a substantial brass standard, seen on the left of the contact-spring. The foot of this standard is fixed on to the woodwork of the coil by a brass screw with ornamental head, while the top part carries the contact-screw, which is arranged to work stiffly in the slotted head. The whole forms a very neat and compact arrangement. All these forms of contact-breakers are designed, it will be seen, to be worked by the magnetism in the iron core of the bobbin. Their operation is as follows:—On the current passing though the primary coil the iron core is magnetised and consequently attracts

the soft iron hammer of the contact-breaker, causing it to approach the iron core. The contact-spring bends, owing to the movement of the hammer, and the platinum contact on it therefore breaks contact with the platinum point on the contact-screw. As the spring and contact-screw are included in the primary circuit this circuit is immediately interrupted, causing a powerful induced current to flow in the secondary, while the hammer of the contact-breaker falls back to its original position, only to repeat its movement so long as the battery is connected up to the coil. In co



FIGS. 19, 20.—SEPARATE CONTACT-BREAKERS.

structing all contact-breakers it is important that the iron hammers are of really soft iron, and the springs either steel or properly stiffened brass or German silver. The contact-screws, in order to avoid their continually working back owing to the vibration, must be provided with efficient set-screws, though for small coils it is sufficient if the contact-screws are arranged to work stiffly in the pillar. The adjustment of the contact-breaker will be found to greatly affect the working of the coil, and in trying to get the longest spark from a spark coil, or the most agreeable shock from a medical coil, the set-screw should be slowly turned while the results are carefully watched. Never make more than a quarter of a turn at a time, as the best position is easily passed.

Of contact-breakers of the second kind, or separate contact-breakers, the form shown in Figs. 19 and 20 is chiefly employed. Although not in any way worked by the iron core it is fitted quite close to one end of the bobbin, in order to economise space and make the whole coil more compact. The contact-breaker consists, it will be seen, of two upright magnets, above which is the soft iron hammer carried by a horizontal spring fixed to a brass pillar. Above this spring is the contact-screw *g*, supported by the metal arm screwed to the top of the wooden standard *r*, that forms one end of

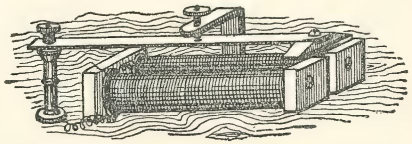


FIG. 21.—SEPARATE CONTACT-BREAKER.

the bobbin. The contact-breaker magnets are in series with the winding on the bobbin, and the action of the contact-breaker is similar, of course, to those worked by the iron core. Another form of the separate contact-breaker much employed for portable sets is shown in Fig. 21. It is largely employed in portable sets, because, being flat, it requires a space of but little height, and is usually fitted in the space covered by the lid when it is shut down. It consists, it will be seen, of two magnet coils, the iron cores of which are joined together at the left-hand ends by a short length of iron bar, and fitted with square-shaped pole-pieces on the right. These magnets are fixed on their sides on the base of the coil, or, in the case of a portable set, on the woodwork forming the top of the case when the set is open.

Above the pole-pieces is the soft iron armature, carried by the thin brass spring, fastened at the left-hand end to the top of a brass pillar. The contact-screw is carried by a brass angle piece, as shown, and the point of the screw works on a platinum contact in the centre of the spring. Separate contact-breakers are chiefly required for coils where the regulation of the strength of the primary and secondary shocks is effected by sliding in and out the iron core, which is therefore not available for working the ordinary form, and also for use in portable sets where it is often necessary to place the coil some way off the contact-breaker, such as at the bottom of the containing case, while the contact-breaker is on the top just inside the lid.

Variable Contact-breakers.

Like the separate contact-breaker the variable contact-breaker is almost exclusively used for medical coils, as with most medical coils it is desirable to be able to alter the rate of vibration of the contact-breaker. Very quick vibrations are required in treating some cases, very slow ones in others. Fig. 22 shows a very simple form, and a form much used in America. The figure shows the contact-breaker in perspective, and part of the coil to which it is fitted. In this form two armatures and springs are provided, the one being an ordinary armature for very quick vibrations, and the other of special form, as shown in the figure. This consists, as will be seen, of the usual iron armature, having a prolongation at one end in the form of a rod, on which slides a brass ball, the distance of this latter along the rod being variable by unslacking the set-screw to be seen on top of the ball. When the coil is connected up to a battery, and quick vibrations are required, the ordinary armature is screwed on to the pillar; but for slow or variable vibrations this is removed, and the one with a ball substituted. On adjusting the contact-screw with this latter form, it will be found the vibrations are very much slower, owing to the momentum acquired by the ball increasing the traverse and the period of time required for the ball to be stopped in one direction and started in the other; while, moreover, the rate of vibration will vary according to the position the ball occupies along the rod. The vibration will be quicker as the ball is moved towards the armature, and slower when moved away from it.

Figs. 23 and 24 show the form of variable contact-breaker employed for all the best class of medical coils, and it is without doubt the most convenient, reliable, and efficient form. At first glance it may appear somewhat complicated

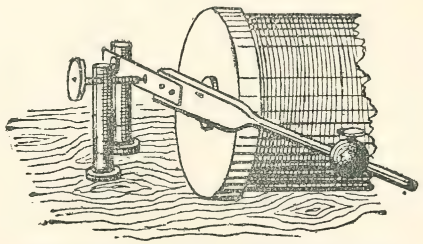


FIG. 22.—VARIABLE CONTACT-BREAKER.

in comparison with the ordinary contact-breaker, which is so simple in its construction; but on better acquaintance much of this disappears, while it will be found that the rapidity of the vibrations are beautifully under control. Fig. 23 shows the contact-breaker from the end of the coil, while Fig. 24 is a side view. Referring to these figures, *x x* are the two magnet coils, consisting of an iron core with bone ends, the wire being wound directly on to the iron core, a layer of paper only being put on. In this form of contact-breaker the iron cores usually consist of a special shaped iron screw with a flat head, the shanks of the screw forming the cores, and the heads the pole-pieces. Above the two magnet

poles is the soft iron armature *a*, of the shape shown, which is fixed at one end of the brass lever *v*, this lever being pivoted in the brass standard *b*. This standard, it will be seen from Fig. 24, has a U-shaped piece at the top, between the arms of which is lightly pivoted on the point of two

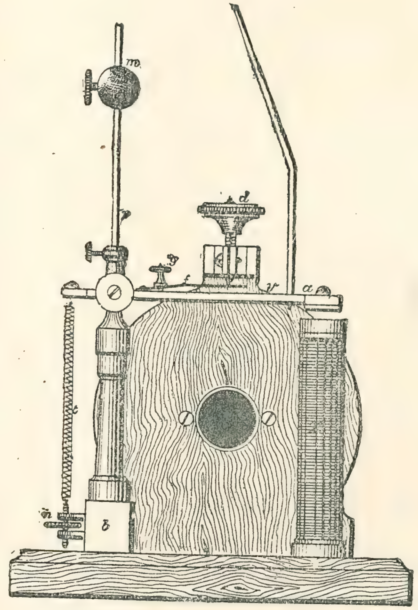


FIG. 23.—VARIABLE CONTACT-BREAKER.

screws the brass lever *v*. The two pivot-screws are each provided with a milled lock-nut to prevent their slacking out with the vibration. The lever, it will be noticed, is not pivoted quite at the end, but at a point about ½ in. from the left-hand side, and between this end of the lever and a projection at the bottom of the stand *b* is stretched the spiral spring t, the tension of which can be adjusted by the milled screw n. Thus the magnets, when energised, attract down the armature against the pull of the spiral spring t.

Almost centrally above the lever v is the brass arm c, fixed at one end to the top of wood end of the coil bobbin—this end being specially shaped to receive it—and carrying at the other the contact-screw d, which works on the light contact-spring f, attached to the lever v, at a point just above the pivots. The tension or amount of projection of this spring can be regulated by the milled-headed screw g.

The portion of the contact-breaker controlling the rate of vibration consists of the upright rod r carrying the ball m. The rod r, which is of aluminium, rises up to a height of 6 in. from the centre of the pivot screws, and then bends over and returns to the other end of the armature. In the figure it is shown broken away at the top to economise space. This rod fixes at the one end into a small brass standard attached to the lever v, centrally above the pivot screws, and at the other, which is tapered slightly, into a hole close by the armature. The rod is thus removable so that the contact-breaker can be used with and without the upright arm and ball. When the contact-breaker is not in use the rod is removed, and placed in the drawer of the case containing the different-shaped electrodes with which such coils are usually provided. The ball m is of brass, nickel-plated, and weighs just over ½ oz. The position of ball upon the left-hand part of the upright rod can be varied by means of the set-screw seen on the left side.

The action of the contact-breaker is as follows: The armature is attracted by the magnets, causing the spring f to part contact with the point of the screw d, thus interrupting the circuit, and allowing the armature to fall back to its original position. The more tension on the spring t, the quicker the armature will recover itself; while the more the screw g is slacked out, the less rapidly will the

spring f break contact with the screw d, and the further will be the traverse of the armature. The higher the ball m is up the rod r the more it will affect the armature, by increasing its traverse and slowing down its vibrations. It will thus be seen that, apart from the ball and rod, the

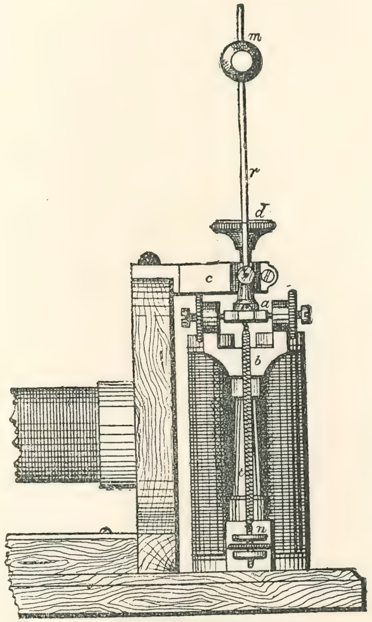


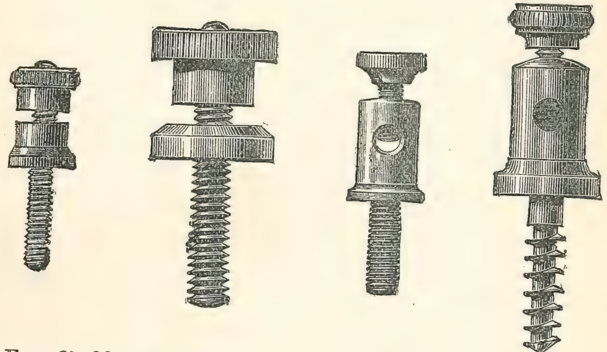
FIG. 24.—VARIABLE CONTACT-BREAKER.

vibrations of the armature are under a certain amount of control by the springs t and g, although to get the very slowest possible vibration (about 60 per minute with most coils) it is not sufficient to regulate by any one of these points alone, but all must be adjusted towards the end desired.

Terminals.

In order to form a convenient method of coupling up the coil to the battery, or making connection to the secondary, apart from the finished appearance it gives to the coil, suitable terminals must be provided for the ends of the primary and secondary windings. These are usually of brass, either lacquered, or, if a better finish is desired, plated.

Figs. 25 and 26 show two forms much used for the primary connections, the terminals being fixed by passing the shanks through the base and running up a nut.



FIGS. 25, 26.—TERMINALS. FIGS. 27, 28.—TERMINALS.

Figs. 27 and 28 show two forms suitable for secondary connections. In these it will be seen the wire is clamped in a hole in the terminal, this method of clamping being preferable for secondary terminals. For large spark coils it is advisable, however, to run the wires from the secondary winding to a "discharger," a useful form of which is shown in Fig. 29, as the handling of wires connected to the secondary of such coils requires great caution, and the use

of a proper discharger may often prevent the occurrence of a disagreeable accident. The form of discharger shown in the figure is fixed on the base of the coil, either at one end or at the side; but some forms in use are fixed, half on each cheek of the bobbin. Referring to the discharger shown in Fig. 29, this consists of two upright brass tubes on the lower ends of which are fixed brass stand-plates, and on

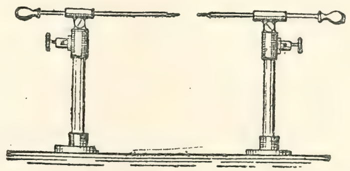


FIG. 29.—A DISCHARGER.

the top of each two brass swivel-pieces, as shown, in which slide two $\frac{1}{8}$-inch brass rods. The outside ends of these rods are fitted with ebonite handles, while the points are drilled centrally to receive fine wire points, which points fit somewhat tightly in the holes. Thus the distance between the discharger-points can be varied by pulling out the ebonite knobs, and different shaped points can be readily inserted as desired. The set-screws just below the swivels are for the ends of the secondary wires.

Bases for Coils.

These should be of polished walnut or mahogany, and the shape will vary according to the kind of coil they are intended for. Thus, for a medical coil it need not be very thick, and should be constructed preferably in two, between which parts the connections to the different parts are clamped, and thus prevent their being injured. For spark coils the base will require to be very much deeper and hollow inside in order to provide sufficient space for the condenser, which is best placed inside the base. Feet should always be provided at each corner to raise the base slightly off the table, as this not only improves the appearance, but also prevents the coil base getting wet, should it accidentally be placed in some spilled solution, &c. Illustrations of several forms of bases for medical and spark coils will be found in Chapters III. and V.

Putting the Coil together.

In putting coils together, the bobbin should first be fixed in its correct position on the base, and the ends of the primary, and, when required, the secondary also, be passed through the holes that should have been previously marked and bored for them. Bobbins are in all medical coils and in most spark coils, fixed by screws passed up through the base into the bobbin, and great care is requisite in screwing up these screws to see that they pass centrally into the bobbin cheek, and not into or near the secondary. Otherwise sparking may take place to these screws, and thence to the coil connection beneath the base.

The contact-breaker should next be fixed, taking care that the correct distances from the end of the iron are observed for the different parts, and when the contact-breaker is finished attention should next be given to the primary and secondary, and any accessory appliances there may be on the base. The different parts being correctly fixed, each portion should be thoroughly tested both for insulation and continuity by means of a galvanometer and battery, and if all is found correct we can proceed to make the different connections underneath the base. These connections will, of course, be made according to the kind of coil as shown in Chapters III. and V.

When joining all wires the joints should be carefully soldered, using resin as a flux, and care must be taken when

inserting the ends of the wires under the contact-breaker, nuts and terminals, to see that, when screwed down, the nuts do not cut or nick the wire, causing it to break.

Condensers.

The condenser of a spark coil consists of a number of layers of thin sheet-foil, insulated by layers of paraffined paper, alternate layers of the tinfoil being connected together, thus forming really two large sheets of foil, one of which is connected to the pillar holding the contact-spring of the contact-breaker, and the other to the pillar carrying the contact-screw. The condenser is thus a bridge across the make-and-break. To M. Fiseau, of Paris, is due the invention of the condenser, the important part played by which in a spark coil can readily be ascertained by experimenting, first without, and then with a good condenser. Its object is to increase the length and strength of the secondary spark, and this it does by absorbing the extra current in the primary circuit at "break," and parting with it at "make." It therefore destroys the detrimental self-induction of the primary coil, allowing the primary current to rise and fall at once to and from its full strength. The self-induction of the primary circuit being reduced to a low point, the sparking at the contact-breaker is, therefore, at a minimum.

The following details of the construction of a condenser refer to the 1-inch spark coil, described in Chapter V., in which chapter the dimensions for the condenser of other size coils will also be found.

Get ready 40 sheets of thin tinfoil 6 × 4 inches (or of a different shape, but similar area if more convenient), and 60 small strips of the same material. Next cut out 60 sheets, 9 × 5 inches, of some good note-paper, which must then be thoroughly soaked in paraffin wax, and allowed to dry. The tinfoil and paper sheets must next be carefully inspected in a good light, first, to see that there are no sharp points in the former, and no holes or thin places in the latter. Now clear a good space on the table or bench, wash your hands, and carefully inspect the cleared portion of the table to see that there are no metal filings near, one of which, if it got between the sheets of the condenser, would render it useless. First, lay ten sheets of the paraffined paper on the table, and on this place one sheet of tinfoil and on one side one of the small strips or connecting tags. On the top of the sheet-foil layer place one layer of paraffined paper, and on this another layer of the tinfoil, leaving the

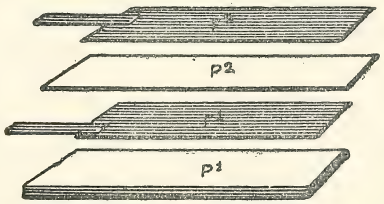


FIG. 30.—BUILDING UP THE CONDENSER.

tag on this one projecting out on the opposite side to the other. In this manner the whole of the sheets are put on, until all are used up. It must be remembered that alternate layers have the connecting tags joined together, and that the tinfoil sheets must be got centrally in the paper separators, leaving a $\frac{1}{2}$-inch space all round. There will thus be twenty sheets of tinfoil connected together on one side, and twenty on the other. The condenser must be finished off with ten layers of the paraffined paper as at the commencement, and the whole condenser afterwards placed in a press, and squeezed firmly together, or, if no press is at hand, placed on a bench with large weights on it. It will then present the appearance as shown in Fig. 31. After it is

thoroughly pressed, it must have a sheet of thick paraffined cardboard or thin wood placed each side, and the whole

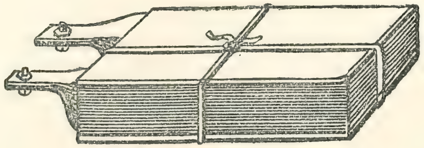


FIG. 31.—CONDENSER FINISHED.

wound tightly with cotton to keep it together. The ends on each side of the condenser must then be pressed together, and the condenser connected on to the coil as shown in Chapter V.

CHAPTER III.

SHOCK AND MEDICAL COILS.

SHOCK COILS is a name applied to all small coils constructed to give mild shocks merely for the purposes of amusement, to distinguish them from the more powerful and scientifically arranged coils designed for the application of induced currents to the cure or alleviation of disease, and known as medical coils.

One of the most essential points of all medical or Faradaic coils is some arrangement whereby the strength of the induced current, or in other words, the intensity of the shock, can be easily and quickly varied, and before passing on to the different forms of medical coils, it will be as well just to glance at the different methods of regulation.

Methods of Regulating Shock.

The three most common methods of regulating the shock are: (1) by means of a thin metal tube, which is so arranged as to slide easily over the iron core; (2) by arranging a switch on the coil base, so that it cuts out certain layers of the secondary; and (3) by the "sledge" method, in which the primary is fixed at one end of the base, and the secondary slides on two guides, so that its position over the primary can be varied from right-over to right-off. Of the three methods, the first is the one most commonly employed, while the last is the one that is capable of giving the most

delicate regulation. Figs. 32, 33 and 34 show diagrammatically these three different methods of regulation; the primary windings in these four figures being indicated by the thick lines, and the secondary by the thin ones, P and P′ being the battery terminals and S and S′ those for the secondary.

The tube method of regulation is shown in Fig. 32. The thin brass tube slides over the iron core, and when the tube is pushed right in, so as to completely cover the core, the shock from either the primary or secondary is at its weakest, but when withdrawn altogether the full strength is obtained. According to the position of the tube, so any modification in the shock can be obtained, although when

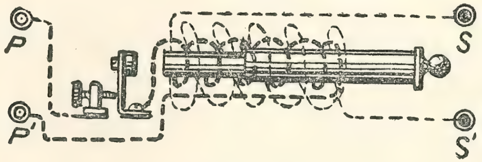


FIG. 32.—TUBE METHOD OF REGULATION.

right in the shock does not altogether cease. The principle of this method of regulation is that we place a closed circuit in such a position to the primary coil that it absorbs its inductive effects. For with every momentary current we have in the primary we get one in a reverse direction in the tube, and thus the induced current tends to neutralise the effects of the battery current, and consequently the shock obtainable from either the secondary or primary winding is very much diminished. As the tube is withdrawn, so there is less surface to be acted upon, and the influence of the regulator is diminished. In the figure P and P′ are the battery terminals, and S and S′ the secondary.

Fig. 33 shows the method of regulating the shock by cutting out some of the layers of the secondary winding. The coil is shown arranged for a secondary shock only, as this method of regulation only affects the secondary winding. Connecting wires are taken from different layers of the secondary coil to the contacts 1, 2 and 3 of switch, the lever of the switch being connected to one of the secondary

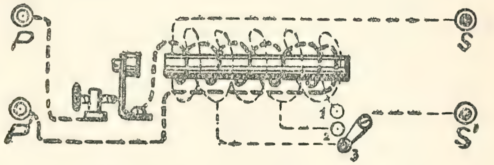


FIG. 33.—SWITCH METHOD OF REGULATION.

terminals. Thus, as the lever is moved from one contact to another, so the shock is increased or diminished, the variations not, of course, being very gradual.

The "sledge" method of regulation is shown in Fig. 34. In coils fitted with this method of regulation the primary

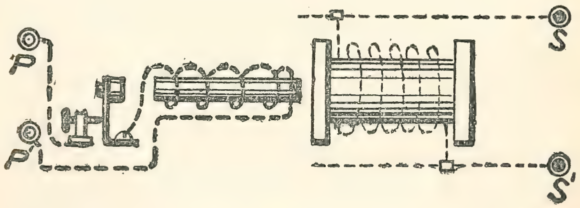


FIG. 34.—SLEDGE METHOD OF REGULATION.

winding, with its iron core and contact-breaking apparatus, is fixed at one end of the base, while the secondary slides on two brass guides, the hole in the secondary being of such a size that it slides over the primary. When the secondary is right over the primary the shock is, of course, at its maximum; and in proportion as it is moved away, so is the

strength of the shock reduced. Since it takes a considerable movement of the secondary coil to much affect the shock, and this movement can be made as slowly as possible, the strength of the shock from coils of this description can be varied most gradually and within very wide limits.

Fig. 35 shows a method of regulating the shock from primary coils devised by the writer, some years ago, in conjunction with Mr. E. J. Wade. The action of the regulator is as follows:—The outside end of the coil is connected to a brass bridge carrying a metal contact-arm which makes contact, the one end on the bridge, and the other on the

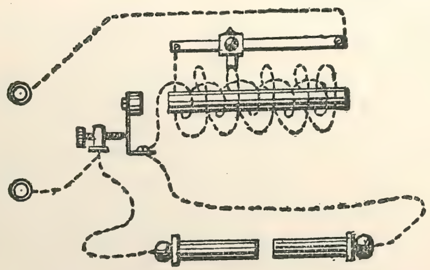


FIG. 35.—A METHOD OF REGULATING SHOCK FOR PRIMARY COILS.

outside layer of the coil, this outside layer being of naked wire. It will thus be seen that when the arm is pushed along to one end of the bridge (the right-hand end in the figures) the top layer of the coil is short-circuited on itself, and forms a closed circuit or metal sheath over the rest of the layers. The effect of this closed circuit on the layers underneath is such as to exercise a "damping" action on them, owing to currents having a reverse direction to those in the coil, being induced in the closed circuit of the regulator, so that the shock to be obtained across the make-and-break at the moment of opening the circuit is reduced to a minimum. It will readily be understood that as the arm *m* is moved back to the other end, so more and more coils are cut out of the closed circuit, and its length thus reduced until at the other end the arm makes contact merely with the brass bridge, and the outside layer has become part of the coil winding again, and adds to, instead of reducing, its effects. Of course as the arm *m* is moved between the two ends of the bridge, so any effects from zero to full power are obtained, and the increase or decrease is as gradual as possible.

Primary Shock Coils.

Primary shock coils are, of course, the simplest form of induction coil, since there is only the one winding, and that of thickest wire, although, notwithstanding this, they can be made capable of giving most powerful shocks. A small coil of this description, fitted with the method of regulation just described, is shown in Fig. 36. Referring to this figure, *f* and *e* are the two battery terminals, while *c* is the contact-post of the interrupter, and *d* the hammer and spring. At the top of the base are the two handles, while at the bottom is the slide and scale of the regulator. The connections to the different parts are indicated by the dotted lines.

The base of the coil, which is $7\frac{1}{4}$ by $4\frac{1}{4}$ by $1\frac{1}{2}$ inches thick, should be cut of a piece of mahogany or walnut, and afterwards carefully sand-papered and French polished. The bobbin (which can be constructed on either of the methods described in Chapter II.) is 3 inches long by 2 inches across the cheeks, the thickness of the cheeks being $\frac{1}{4}$ inch, and the hole through the centre of the bobbin $\frac{3}{8}$ inch. The iron core consists of about 90 lengths of No. 22 iron wire. To wind the bobbin, about $\frac{1}{2}$ lb. No. 24 double cotton-covered wire will be required, and this must be wound on layer upon layer, until eleven layers are put on, and this eleventh layer will finish at the right-hand end of the bobbin. This

end of the wire is then secured by drilling two holes in the bobbin cheek side by side, and passing the end of the wire through one hole from the inside to the outside, and back again through the other hole to the inside, leaving a $\frac{1}{2}$-inch tail projecting.

For the regulating layer we shall require about seven yards of No. 22 naked copper wire; but before winding on this layer, three wrappings of thick note-paper must be put on over the last layer of the other winding, and the paper well basted with paraffin-wax. This will make a firm and even surface, on which the regulating layer can be wound—

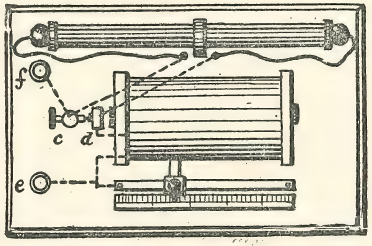


FIG. 36.—PRIMARY SHOCK COIL.

a most important point, for the end of the brass spring *m*, it will be seen, slides along and makes contact with the bottom of this layer. If the three layers of paper are not sufficient, then a piece of thin cardboard should be bent round. In order to prevent the different turns of wire in this regulating layer touching one another, and thus making a permanently closed circuit, some thin twine, of not larger diameter when slack than No. 22 B.W.G. wire, is wound on at the same time, thus leaving a turn of twine between each turn of wire, as shown in Fig. 37. Previous to winding, however, the beginning of the naked wire must be soldered on to the projecting tail of the insulated layer beneath. If a certain amount of tension is kept on the twine while winding, it will be found to sink slightly below the level of the naked wire, after the manner shown in Fig. 37. When this layer is finished the twine must be fastened off by slipping the end under the last coil and tying it, while the end of the wire is passed through a small hole in the bobbin cheek and cut off, leaving a projecting end of 6 inches. The naked No. 22 wire should not be continued right up to the left-hand cheek of the bobbin, but stopped at about $\frac{1}{4}$ inch or $\frac{3}{8}$ inch off, as this will enable the contact-spring *m* to slide off all but the last turn of the

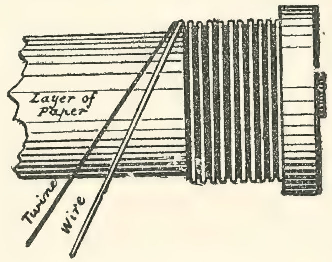


Fig. 37.—Method of winding last layer.

wire, so that no turns of the regulating layer are short-circuited when the pointer is at the left-hand end of the index.

We can now screw the bobbin back on to the base, and proceed to fit the regulating gear, contact-breaker, and terminals. Fig. 38 shows an end view of the coil with the left-hand cheek removed, showing the position of the contact-spring and slide *m* and the guide *n* of the regulator. The guide is of brass, and is supported off the wooden base, as shown by two feet, also of brass. On the guide runs the slide and spring *m*. The slide is of brass, with ebonite or boxwood knob, and the thin spring, also of brass, is soldered or screwed to the underneath part of the slide, so that it

holds it on the guide. The front part of the spring bears with moderate pressure on the uninsulated layer of wire, as in Fig. 38, and the outside lapping of velvet, when it is put on, only extends as far down on each side of the bobbin as shown in the above-mentioned figure, so that it does not interfere with the working of the spring.

Referring to Fig. 36 it will be seen that the inside end of the coil is connected to the contact-spring and the outside end to the guide of the regulator, this guide being also connected to terminal *e* on the base. The other terminal *f* is connected to the contact-pillar, while the two handles are connected, one to the contact-pillar and the other to the con-

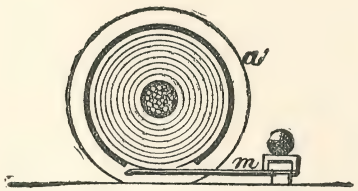


Fig. 38.—Section through primary coil.

tact-spring. On connecting up a battery to the coil, and adjusting the contact-screw of the make-and-break, the soft-iron hammer on the spring should vibrate rapidly, giving out a humming note, the pitch of which will vary as the contact-screw is adjusted. The note will be lower as the contact-screw is slacked back, and higher as it is tightened up, owing to the more rapid vibration. On taking hold of the handles while the contact-breaker is vibrating, a smart shock will be felt if the regulator is to the left-hand side, which diminishes as it is moved to the right. The action of the coil is as follows:—The magnetism in the core suddenly ceases when the contact-breaker is attracted, and with the cessation of the current each turn of the coil acts inductively on its neighbours, giving rise to an induced or extra current of higher E.M.F., which, in its endeavour to complete its path round the circuit, can only pass by way of the handles and the person holding them, and hence the shock. The shock from a primary coil is only felt on breaking the circuit, although there is also an induced current on completion; but this is in opposition to the battery current, and its only effect is to momentarily impede the filling of the coil. The induced current on breaking the circuit is in the same direction as the battery current, and thus the nature of the current passing through the person holding the handles is partly Galvanic and partly Faradaic.

The strength and character of the shock from the coil is, it will be found, influenced by the rate of vibration of the hammer, or, in other words, by the number of times per second the circuit is interrupted. On slacking back the contact-screw, so as to get a slower rate of vibration, the shock will be found increased in intensity, while there becomes almost a distinct interval between the shocks. On tightening up the screw the reverse is the case, and this is because the iron core takes a certain amount of time to take up its magnetism, or the coil to get fully charged, as it were. Thus, with very quick breaks, the current from the battery does not get sufficient time to rise to its full strength, nor the iron core to thoroughly acquire or part with its magnetism. Similarly the position of the regulator will be found to influence the rate of vibration of the contact-breaker, which can be detected by the alteration in the note as the piece *m* is moved along the guide *n*. This arises from the fact that when there are no coils of the regulating layer in circuit, the impedance of the primary winding is greatest; the shock is therefore strongest, although the battery current passing is weakest. With the whole of the regulating layer closed on itself, as happens when the piece *m* is to the left-hand side, the bulk of the inductive effects of the primary winding are absorbed by this layer, the impedance of the coil is low, and

the shock practically nil, notwithstanding a larger battery current is passing.

Medical Coils.

Most medical coils are so arranged that both a primary and secondary shock can be administered, and in the larger forms a tertiary one also. The reason for this is because the actions of the primary and secondary currents on the human body are held by men who have investigated the subject to have a very different effect from one another.

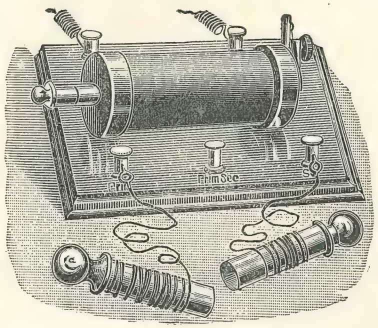


FIG. 39.—SMALL MEDICAL COIL.

Figs. 39, 40 and 41 show a very handy little medical coil, Fig. 39 being a perspective view, Fig. 40 a section, and Fig. 41 an elevation from the contact-breaker end. The coil has two windings—a primary and secondary—and the three terminals on the top of the board marked, "Prim.," "Prim. Sec.," and "Sec.," respectively, allow either a primary, a secondary, or a combined primary and secondary to be obtained.

The wood base of the coil is 6 inches by $4\frac{1}{4}$ inches, and should preferably be constructed in two parts, *f* and *x*, as shown in the figures. Referring to Fig. 40 the top part *f* is $\frac{3}{8}$ inch thick, while the bottom *x* is $\frac{1}{4}$ inch, and the two are fastened together by six screws passed through the bottom part into the top. Thus the wires connecting the different parts of the coil, which are let into grooves in the bottom side of f, are completely hidden, and secured in place when the part x is screwed to it. These, as well as the five

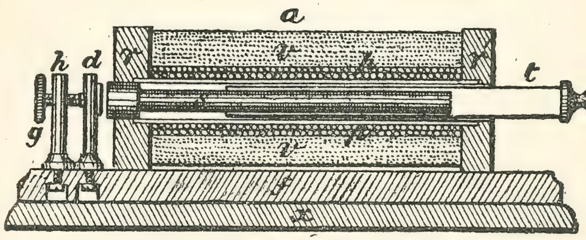


FIG. 40.—SMALL MEDICAL COIL (SECTION.)

terminals, "sec." "prim. sec.," and "prim.," M and N, must afterwards be properly fixed at the positions shown in Fig. 39.

The wood bobbin r is 4 inches long by $1\frac{3}{4}$ inches across the bobbin ends, which are $\frac{3}{8}$ inch thick, and has an iron core a

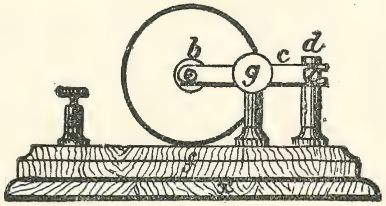


FIG. 41.—END ELEVATION.

composed of a piece of sheet iron rolled into a spiral and filled with lengths of iron wire, one end of the core being fitted with a solid iron cap at the contact-breaker ends of the coil. The regulating tube, which, it will be seen, slides in and out at the opposite end to the contact-breaker, is a thin brass one

of such diameter that it slips easily over the iron core, and has a small knob soldered on to the end, by which it is moved backwards and forwards. The contact-breaker is of the form shown in Fig 17, Chapter II., g being the contact-screw, c the spring, and b the hammer head.

The primary windings p consist of two to four layers of No. 22 cotton-covered wire, over which are wound 15 layers of No. 36 silk-covered copper for the secondary v. Both windings must be carefully wound as directed in Chapter II., after which the bobbin can be affixed to the base.

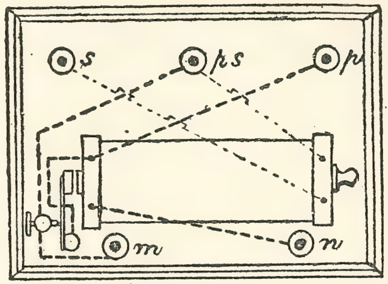


FIG. 42.—CONNECTIONS FOR SMALL MEDICAL COIL.

Previous to screwing down the bobbin, it should have a covering of black or dark blue velvet, put over the last layer of the secondary, which will greatly improve the appearance of the coil. Referring to Fig. 42, which shows the connections of the coil, the outside end of the primary is, it will be seen, connected to the terminal n, and the inside to the post carrying the contact-hammer and spring, the post carrying the contact-screw being connected to the other battery terminal m. A wire is also run from the contact-post carrying the contact-screw to the terminal PS, and another from the inside end of the primary to the terminal P. The inside end of the secondary is connected to the terminal P S, and the outside to the terminal S. These connections having been properly made, the part x of the base can be screwed on to the part f, and the coil is complete.

On connecting up a battery of one or two cells to the terminals m and n, and adjusting the contact-breaker, it will be found that a smart shock can be obtained. First, if the two handles are connected to P and P S; second, if connected to P S and S; and third, if connected to S and P. The first of these shocks is a "primary" shock, the second a "secondary," and the third a combined "primary and secondary" shock, the two windings in this latter case being connected in series and working together. It will be found, on experimenting, that the shock obtained from the primary is the weakest, that from the secondary much stronger, while the combined primary and secondary is the strongest, the strength of the shock in each case being variable by moving in and out the regulating tube.

Referring to Fig. 38, presuming the positive pole of the battery to be connected to M, then on the breaking of the circuit by the interrupter, the direction of the shock will be in the primary from terminal P S to P, and from the secondary from S to P S, and from the primary and secondary combined from S to P. The induced current in the primary will be in the same direction as the inducing current on the opening of the circuit, and the induced current in the secondary is in the same direction as the induced current in the primary; thus, as these two windings are connected in series (inside end of the one to the outside of the other), the induced current proceeding from the one coil will augment that of the other.

Bath Coils.

For the application of electricity to the human body by means of the electric bath, a specially constructed and somewhat powerful coil is necessary.

Figs. 43, 44, and 45, show a form of the bath coil in side elevation, plan, and perspective respectively. The coil is provided with a primary, secondary, and tertiary winding, and on one side of the coil is the switch x, operated by the handle k, which allows either a primary, secondary, tertiary, primary and secondary, secondary and tertiary, or combined primary, secondary and tertiary shock to be obtained,

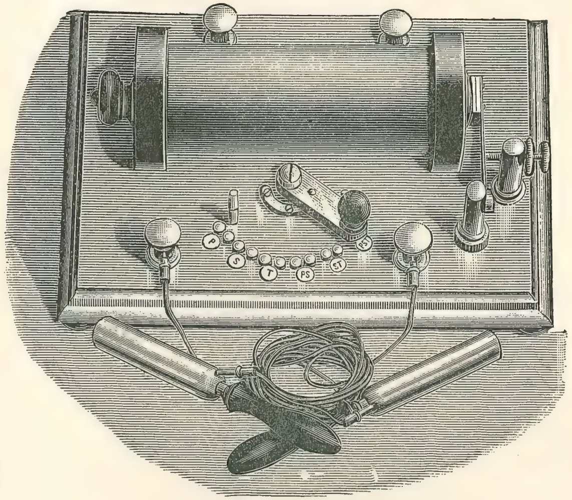


Fig. 43.—Bath coil.

the different position for the handle of the switch being indicated by the labels P, S, T, P S, S T, and P S T. The two battery terminals are marked + and −, while h and h' are the terminals to which the handles or bath electrodes are connected. The base of the coil, which is of polished walnut, is made in two parts, as described for the previous coil, the dimensions of the top part being 10 inches $\times$ $6\frac{7}{8}$ inches $\times$ $\frac{9}{16}$ inch, and the bottom $10\frac{1}{2}$ inches $\times$ $7\frac{3}{8}$ inches $\times$ $\frac{5}{16}$ inch.

The bobbin ends are 3 inches × $\frac{5}{8}$ inch, and the extreme length of the bobbin is 7 inches, the ends being made of any hard wood ebonised. The iron core, which is composed of No. 22 highly-annealed iron wire, is $6\frac{1}{2}$ inches in length by $\frac{1}{2}$ inch thick, the ends being soldered together so as to form one solid mass, and thus allow the regulating tube to slide easily over the one end, while the other is forced into the brass bush *r*, which bush is in turn forced into the right-hand cheek of the bobbin. The bobbin is built up after the manner described in Chapter II.

The switch allowing the different kinds of shock to be administered consists of the plated brass lever *x* operated by

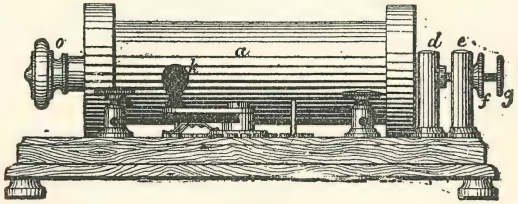


FIG. 44.—SIDE ELEVATION OF BATH COIL.

the handle *k*, Figs. 47 and 48. Beneath the handle, and on the underneath side of *x*, is the ebonite block *w*, carrying two contact-springs, the one of which makes contact between the contacts (see Fig. 46) on the base and the pillar *m*, and the other between the adjoining contact and the circular metal strip *n*. The metal part *x* swings on the screw on the top of the pillar *m*, and the shorter of the two springs *c* being in connection with *x*, it follows that the contact on the base on which the springs happen to be resting is put into electrical connection with the pillar *m*. The longer spring *c* is perfectly insulated from the lever *x*, and so bent that the one end presses on the contact adjacent to that on which the shorter spring is resting, while the other rubs on

the brass strip *n*, and therefore the contact on which this spring is resting is electrically connected with *n*. Thus, when the handle of the switch is over, let us say, the label *p*, the one contact-spring *c* is on the right-hand contact-stud and the other on the left-hand one, and the two ends of the primary are connected to the pillar *m* and semicircular brass piece *n* respectively. Since the terminal *h* is connected to the pillar *m*, and the terminal *h′* to the brass piece *n*, it follows that these terminals, and also the electrodes attached to them, are in contact with the ends of the primary.

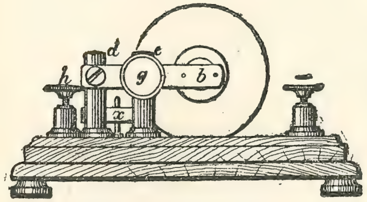


FIG. 45.—BATH COIL.

FIG. 46.

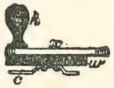


FIG. 47.

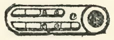


FIG. 48.

SWITCH LEVER.

For the primary 6 oz. of No. 24 silk-covered copper wire will be required, and this must be wound on layer upon layer, as previously described.

A layer of well paraffined paper must be put on over the primary previous to winding the secondary, and also over the secondary when finished before winding the tertiary.

The secondary coil is wound with 8 oz. No. 36 silk-covered wire, the ends being brought out at the opposite cheek to the primary. The tertiary coil is wound with 8 oz. No. 36 silk-covered wire, the ends of the coil being brought out at the same end of the bobbin as the secondary. The connections of the coil are clearly shown in Fig. 49. Starting from the left-hand battery terminal marked +, a

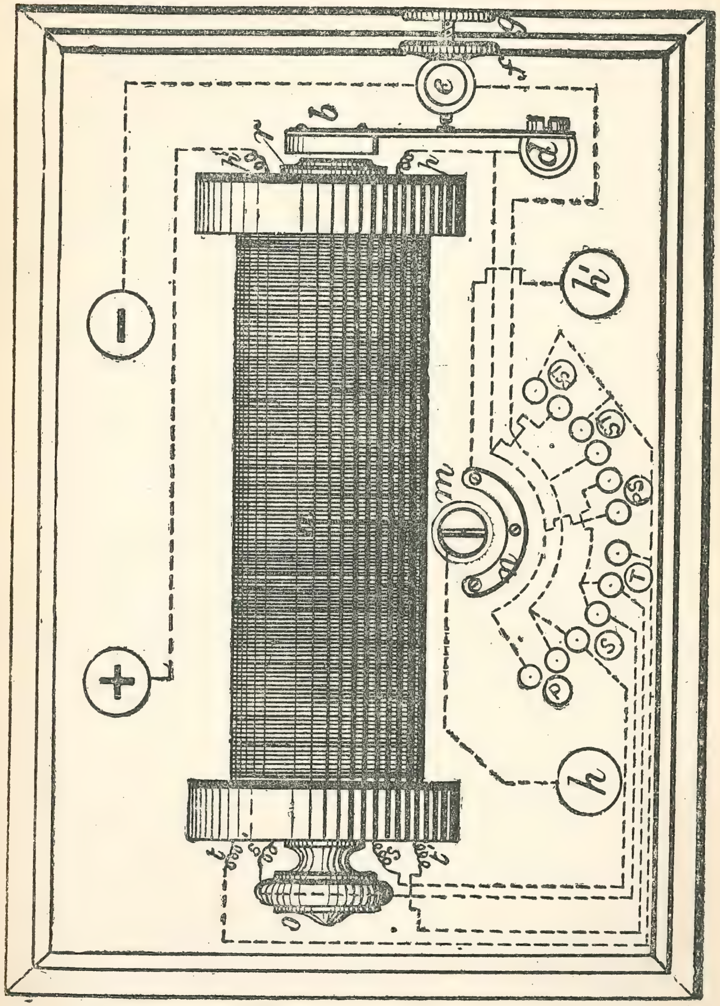


FIG. 49.—CONNECTIONS OF BATH COIL.

wire runs, it will be seen, to the outside end, p^1 of the primary coil, the inside end p being connected to the pillar d, carrying the contact-spring and hammer. A wire is also run from this pillar to contact-studs Nos. 1, 7, and 11 (counting from the left-hand side) of the switch. The other battery terminal, marked $-$, is connected to the contact-pillar e, carrying the contact-screw, and this pillar is also connected to switch contact-studs 2, 3, and 9. The inside end s of the secondary coil is connected to the contact-stud 3, while the outside end s^1 is connected to the contact-stud 4. The outside end t^1 of the tertiary coil is connected to the contact-stud 5, while the inside end t is connected to the contact-stud 6. The additional connections between the contact-studs 4, 5 and 8 must also be made, and likewise the connections between the terminal h and pillar m and the terminal h^1 and the semicircular contact-piece n.

To follow out the course of the induced currents in Fig. 49, there is first the primary induced current starting from the primary coil to p, contact-stud No. 1, contact-piece n, terminal h, terminal h', pillar m, contact-stud No. 2, contact-pillar e, terminal $-$, battery, terminal $+$, back to primary coil. The secondary induced current starts from the secondary winding to contact-stud 3, terminals h' and h, contact-stud 4, and back again to secondary. The tertiary current runs from tertiary winding to contact-stud 5, through handles to contact-stud 6, and back to tertiary by the end t. The combined primary and secondary currents run from end of primary p to contact-stud 7, through the handles to contact-stud 8, then to contact-stud 4, through the secondary winding to contact-stud 3, contact-pillar e, terminal $-$, battery, terminal $+$, and back to primary. The combined secondary and tertiary currents run from end s of secondary to contact-stud 3, then to contact-stud 9, through handles to contact stud 10, then to tertiary coil, contact-stud 5, contact-stud 4, and back to secondary winding. The combined primary, secondary, and tertiary currents run from primary coil to contact-stud 11, through handles to contact-stud 12, from there to tertiary coil, contact-stud 5, contact-stud 4, secondary coil, contact-stud 3, contact-pillar *e*, terminal −, battery, terminal +, and back to primary coil.

Another way of connecting up the coil shown in the last article is illustrated in Fig. 50, the two terminals *h* and *h'* and the post *m* and contact-piece *n* being omitted, as their connections are the same as shown in Fig. 49. The main difference between this method and that previously described

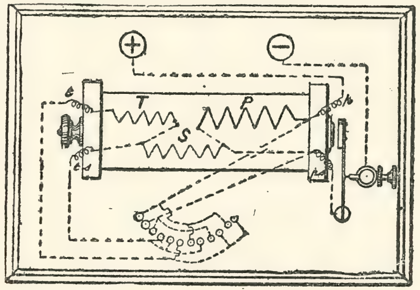


FIG. 50.—ANOTHER METHOD OF CONNECTING UP BATH COIL.

is that whereas in Fig. 47 we had the six ends protruding from the wound bobbin, we have in Fig. 50 only four, a state of things that is apt to prove perplexing to many on first examining a coil of this description. The matter is at once made clear, however, on glancing at Fig. 53, as it will be seen that the three different windings, marked *p*, *s*, and *t* respectively, are all internally connected. Thus ends *p* and *p s* will give the primary shock, ends *p s* and *t s* the secondary, and ends *t* and *t s* the tertiary.

Another form of coil, much used for electric baths, is shown in Figs. 51 and 52. The coil has a primary winding only,

and this winding being of somewhat large wire, a primary current of comparatively low voltage is obtained, and the coil is thus specially suitable for the electric bath, and the treatment of the abdomen by faradisation. The strength of

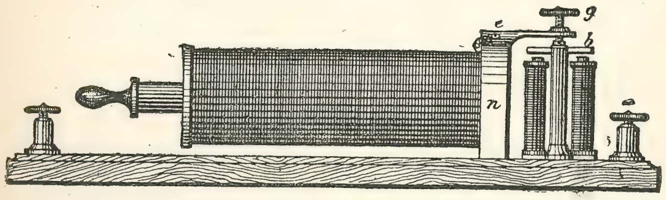


FIG. 51.—ANOTHER FORM OF BATH COIL.

shock is regulated in two manners—first, by sliding in and out the movable iron core; and second, by a switch having five contacts, so that as the position of the arm of the switch is altered, either 2, 4, 6, 8 or 10 layers of the

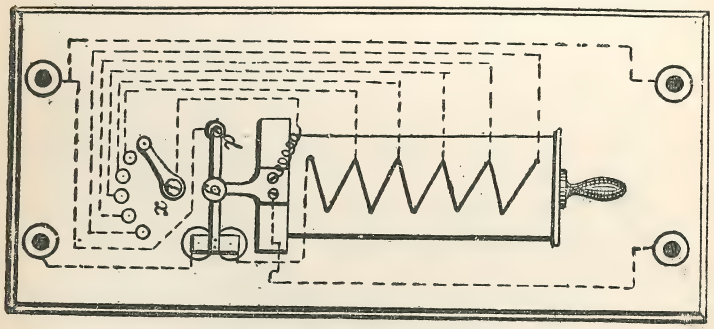


FIG. 52.—CONNECTIONS FOR COIL.

winding are in circuit. This switch is not shown in either of the above-mentioned figures, but a separate view is given in Fig. 52, showing the position of the switch, and the necessary alterations in the connections for its addition to the coil.

Sledge Coils.

The Dubois-Reymond, more commonly called "sledge" coils, owing to the secondary working on a sledge or slide, are undoubtedly the most convenient and efficient for medical purposes. In these coils the primary winding is fixed while the secondary is movable, so that its position over the primary can be adjusted, and thus the induced currents in the secondary can be made very powerful or very weak, while the transition to the intermediate strength is capable of being produced almost imperceptibly. Moreover the secondary coil being removable, additional secondary coils, wound with finer or thicker wire, can be kept by for use in cases where either a higher or lower potential secondary current is required. The coils are generally arranged to give a primary shock as well as secondary—the variations in the strength of the primary shock being produced by varying the position of the iron core, which is made removable for this purpose. The insertion or removal of the iron core also affects the strength of the secondary shock, though the alteration of the position of the secondary itself, as described above, is mainly relied on for regulation. The iron core being removable, a separate make-and-break is necessitated.

Figs. 53, 54, 55 and 56 show in side elevation, end elevation and plan respectively, a form of the Dubois-Reymond or sledge coil.

The wood base of the coil, which should be of polished walnut or mahogany, is 14 inches long by 5 inches wide, and $\frac{5}{8}$ inch thick. At $3\frac{1}{4}$ inches from the right-hand end is fixed the upright standard *n*, carrying the primary bobbin *a*, which is secured to the standard by two screws, which union can be further strengthened with glue if desired.

The iron core in this coil, it will be noticed, slides in and out at the contact-breaker end, and for this reason the

handle actuating it must be made sufficiently long to prevent the hand interfering with the contact-breaker when pushing the core right home. The iron core consists of a tube made by rolling up thin sheet iron into a tube of the required diameter, and filling up the centre with lengths of

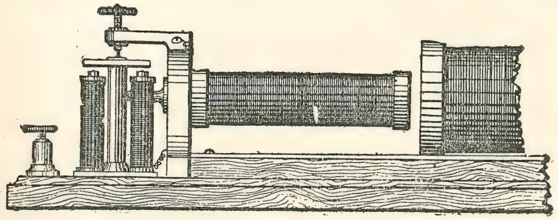
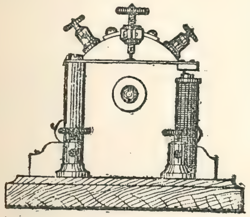
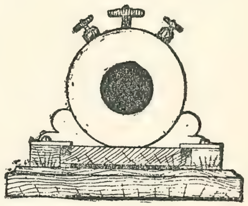


FIG. 53.—SLEDGE COIL.

No. 22 iron wire, the wooden handle being driven into one end of the tube. The primary bobbin is 5 inches long by $1\frac{1}{2}$ across the bobbin ends, with hole in centre, while the secondary bobbin is 5 inches long by 3 inches across the bobbin ends, with the hole in the centre $\frac{1}{8}$ inch larger than





FIGS. 54, 55.—SLEDGE COIL.

bobbin ends of the primary, in order to allow the primary to slide easily through the secondary; both bobbins should be constructed of polished walnut or mahogany to match the base.

The guides for the secondary bobbin consist of two lengths of wood, *x* and *x*′, fastened one each side of the base, as shown in Fig. 56, these lengths being secured to the base by screws passed up from underneath. At the top of each length of wood is a strip of brass $\frac{1}{16}$ inch thick, and secured to the wood guides by four round-head brass screws. The slide consists of a piece of wood (mahogany or walnut, according to the construction of the base) $4\frac{3}{4} \times 3$ inches, the bottom being cut away, to allow the slide to move steadily, instead of in a series of jerks. Apart from this, it is necessary that the slide fits the grooves nicely, and this is done by placing two U-shaped springs on the top of the slide—one on each side—these springs being fixed by a screw in

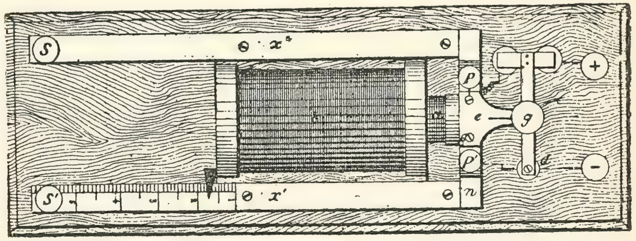


FIG. 56.—PLAN OF SLEDGE COIL.

the centre, and so arranged that their two ends press against the metal strips on the top of the side-pieces. The ends of the wire from the secondary winding are connected one to each spring, so that the springs serve the double purpose of keeping the slide pressed firmly to the base, and also completing the connection of the secondary winding to the terminals S and S′, by way of the metal strips.

The contact-breaker is fixed at the right-hand end of the coil, and is of the form described on p. 33.

The primary bobbin is wound with six layers of No. 22 silk-covered copper wire, which must be very evenly laid on, so that the complete bobbin presents a perfectly even surface, the surface of the last layers being slightly below

the cheeks of the bobbin. The secondary is wound with 14 layers of No. 36 silk-covered copper wire, carefully and

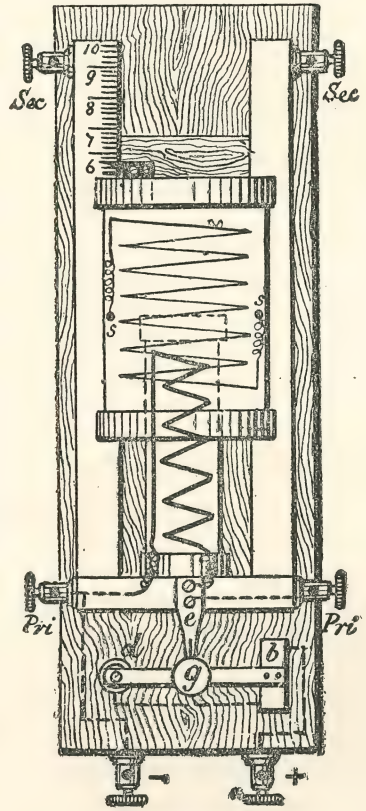


FIG. 57.—CONNECTION OF SLEDGE COIL.

evenly wound on, the outside of the bobbin, when completed, being covered with a wrapping of velvet. Spare secondary coils can, of course, be made, and if care is taken in finishing up the slide and fitting the secondary on to it, there will be very little difficulty in making the different bobbins fit in the guides without touching the primary. Each additional secondary coil will, of course, require its own slide and side contact-springs. The number of turns used on coils of this description is usually primary 500 to 700 turns, secondary 5000 to 10,000 turns.

Fig. 57 shows the connections of the coil of this description, the thick lines denoting the primary and the fine ones the secondary.

Portable Coils.

Portable coils are now to be obtained in a very large number of different forms, these coils, since the introduction of dry batteries, having found much favour with the medical profession; while, moreover, the majority of persons who

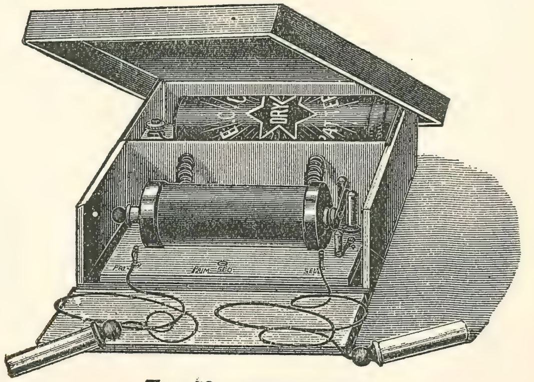


Fig. 58.—PORTABLE COIL.

desire to have coils for self-treatment usually prefer to have them in the form of a set that can be quickly set up and put away when finished.

Fig. 58 shows an inexpensive little portable set, consisting

of a coil as described on p. 55, fitted into a case as shown, with a dry cell at the back. The front part of the case falls over outwards when released, thus allowing the handles and coil to be readily got at.

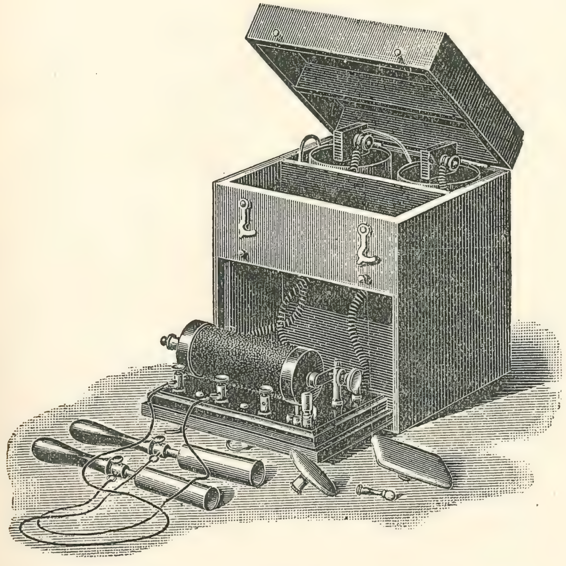


Fig. 59.—PORTABLE MEDICAL COIL.

Fig. 59 shows another very convenient form of portable set. The case is of polished walnut or mahogany, with a division at the top for the electrodes, and another at the back for the two dry cells, as shown. The coil is fixed on a hinged portion of the front, as in the figures, so that it can readily be got at for adjustment, &c.

Passing on to larger and more elaborate portable coils, we come to the Dubois-Reymond set, a portable set which, when fitted with all its accessories, forms one of the most powerful, useful and convenient. When worked by dry batteries, and supplied with the variable make-and-break, as in Figs. 60, 61 and 62, it really leaves little further to be desired.

As usually made up, the set consists of a polished rosewood, walnut or mahogany case, the lid, as will be seen from the figures, being of greater depth than the bottom of the case. The lid is hinged to the right-hand end of the case, and at $2\frac{3}{4}$ inches from this end is fixed the thin upright

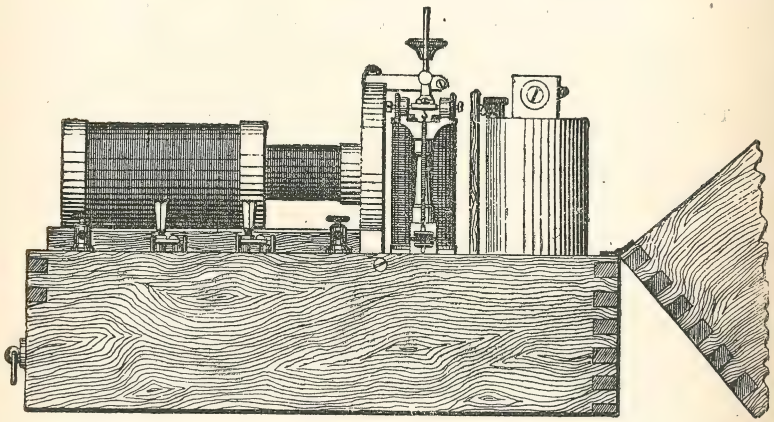


FIG. 60.—PORTABLE SLEDGE COIL SET.

partition (also of polished wood) that divides the batteries from the coil. This partition starts from the very bottom of the case, rising up to the height shown in Fig. 60. Left of this partition is the supporting base of the coil and its accessory parts, this base being flush with the top of the bottom part of the case, as shown in Fig. 60, the space so formed underneath being fitted with a drawer that pulls out at the left-hand end of the case. The drawer can be pulled out by the handle seen to the left of the case; but when the lid of

the case is shut down and locked, the drawer is secured by a movable pin, seen just below the lock, which prevents it being pulled or falling out.

The base of the coil, which is usually of polished wood to match the case, though sometimes of ebonite, is secured in its place by three brass screws, one on each side, and one at the left-hand end. The side-pieces or runners for the secondary bobbin are of polished wood similar to the case and base, fitted with brass strips at the top, as has been pre-

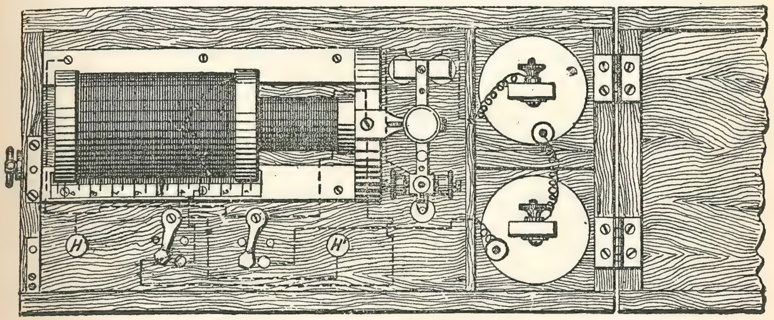


FIG. 61.—PORTABLE SLEDGE COIL SET (PLAN).

viously explained, these runners butting up against the upright standard (also of polished wood) carrying the primary bobbin.

Between the upright standard and the battery partition is the make-and-break, which is similar in form to that described on p. 37.

Referring to Fig. 61, just below the coil will be seen two switches, that on the right being to open and close the battery circuit, while that on the left enables either the primary or secondary induced current to be directed to the electrodes. With the battery switch the contacts are simply "on" and "off," but with the left-hand switch the contacts are "primary" and "secondary," that on the right being the primary and that on the left the secondary. On each side of the switches are two terminals, H and H', these being the connections for the flexible wires of the electrodes.

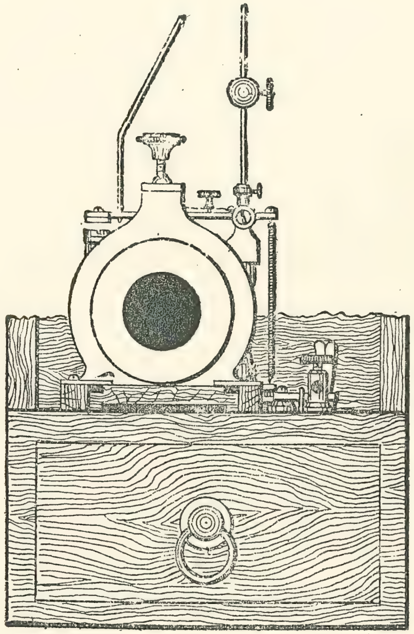


FIG. 62.—PORTABLE SLEDGE COIL SET.

The connections to the different parts of the coil are shown by the dotted lines and the spirals of wire in the case of the battery connections. The battery circuit runs from the carbon terminal of the top cell (Fig. 61) to coils of contact-breaker bobbins, thence to pillar of contact-breaker, on the

top of which is pivoted the armature, then to contact-screw carried by arm on top of the wood upright, inside end of primary, outside end, switch arm, and then back to zinc terminal of lower cell. As shown in the figure, the battery switch is off and the circuit open. The primary induced current flows from the outside end of the primary winding to terminal H, through the electrodes to terminal H', thence to lever of left-hand side switch, left-hand contact, the switch being in the position shown in the figure, then to arm on top of wood standard and back to inside end of primary. The secondary induced current runs from outside end of secondary winding to right-hand contact of left-hand switch, switch lever, the lever being in the opposite position to that shown in the figure; thence to terminal H', electrodes, terminal H, and then to inside end of secondary winding by way of the metal strip on the top runner of the secondary bobbin, the outside end being in a like manner in connection with the bottom runner. The various shaped electrodes are carried in the wood drawer before described, and into this drawer is also placed the aluminium upright arm and brass ball of the contact-breaker when not required.

Street Coils.

"Street coil" is a name that has been applied to all shock coils designed for use at fairs, in the streets, and other public places, where, on the usual "high days and holidays," the diversion-seeking holiday-makers are "electrified" at a charge of a penny per head. Every one, of course, is familiar with the general appearance of such coils—the massive dial, formidable-looking bobbin, large terminals, and showy brass mountings, the whole being supported on a small hand-truck, while by the side stands the loquacious proprietor extolling loudly, though not always too truthfully, the virtues of "'lectricity," which, in his estimation, appears to be a sort of panacea for all ills to which the flesh is heir.

Very numerous are the different forms in which street coils are to be found—indeed, it is not too much to say that although there are, of course, certain points alike in all these coils, one rarely sees two coils of the same design, this being due, no doubt, to a great extent to the fact that each proprietor partly, if not wholly, designs and constructs his own coil, his main endeavour being apparently to outvie in showy and mysterious appearance anything he has previously seen. A showy and attractive appearance is without doubt the most important point to be looked to in designing a coil of this description, and the one which is in a great measure responsible for some of the very curious forms to be seen. Plenty of brass mountings are always arranged for, and all terminals and contacts made unusally heavy.

A bold dial is another important item. This should preferably be marked up to a high number of gradations, the index-hand being actuated by drawing out the brass regulating tube of the bobbin, the tube being connected by a thin cord or wire, though the apparatus must be so arranged that there is apparently no connection between them, the impression possessed by the majority of onlookers being that the pointer is actuated by the electric current in some mysterious manner. Were it evident that the pointer was actuated by means of a cord, much of the interest of the onlookers would disappear. Another point to which attention should be paid is to have a large and loud-sounding contact-breaker, the mysterious humming of the interrupter having a wonderful effect, both in attracting the passers-by, as well as being a visible indication to them of the presence of an electric current.

In many coils there are usually the addition of one or two electric bells, of more or less curious design, and a small motor, and frequently an arrangement to ring a bell or make a figure move when the index-hand indicates a certain strength on the dial. Suitable switching arrangements are, of course, made both for switching on and off the battery current, as well as directing either the primary, secondary, or combined primary and secondary current to the handles.

Fig. 63 shows a form of street coil which, while divested of much of the unnecessary paraphernalia of many street coils, proves, when made up, a most serviceable instrument, combining efficiency with a showy and attractive appearance. Referring to this figure, the base of the coil is of polished walnut or mahogany, having a fancy moulding run round as shown. At each corner of this base, and also at the centre of each side, are fixed massive brass pillars of the shape shown, joined together by brass rods, which rods fix into holes in the balls of the pillars. From the top end of the base rise two polished brass pillars, having flanges at the bottom and a squared portion at the top, finishing off with an ornamental point, as illustrated. These pillars, which are, of course, hollow, are secured to the base by screws passed through the flanges, and the squared portions at the top carry the dial. The containing case of the dial may be either of polished mahogany like the base, or of polished brass to match the pillars. Just below the dial, and slightly in front of it, is an electric bell that can be set in action by a small switch (not visible) and also by the regulating tube when drawn right out, and the needle indicates its fullest strength, viz. 170. This bell can, of course, be of any desired form, the form shown being that having two gongs, and the hammer working from one gong to the other. The gongs are mounted on a polished mahogany board, which is supported off the base by four brass pillars, the movement of the bell being attached to the underneath side of the board.

The coil itself is supported on a separate base, which base is in turn fixed to the main base just in front of the bell.

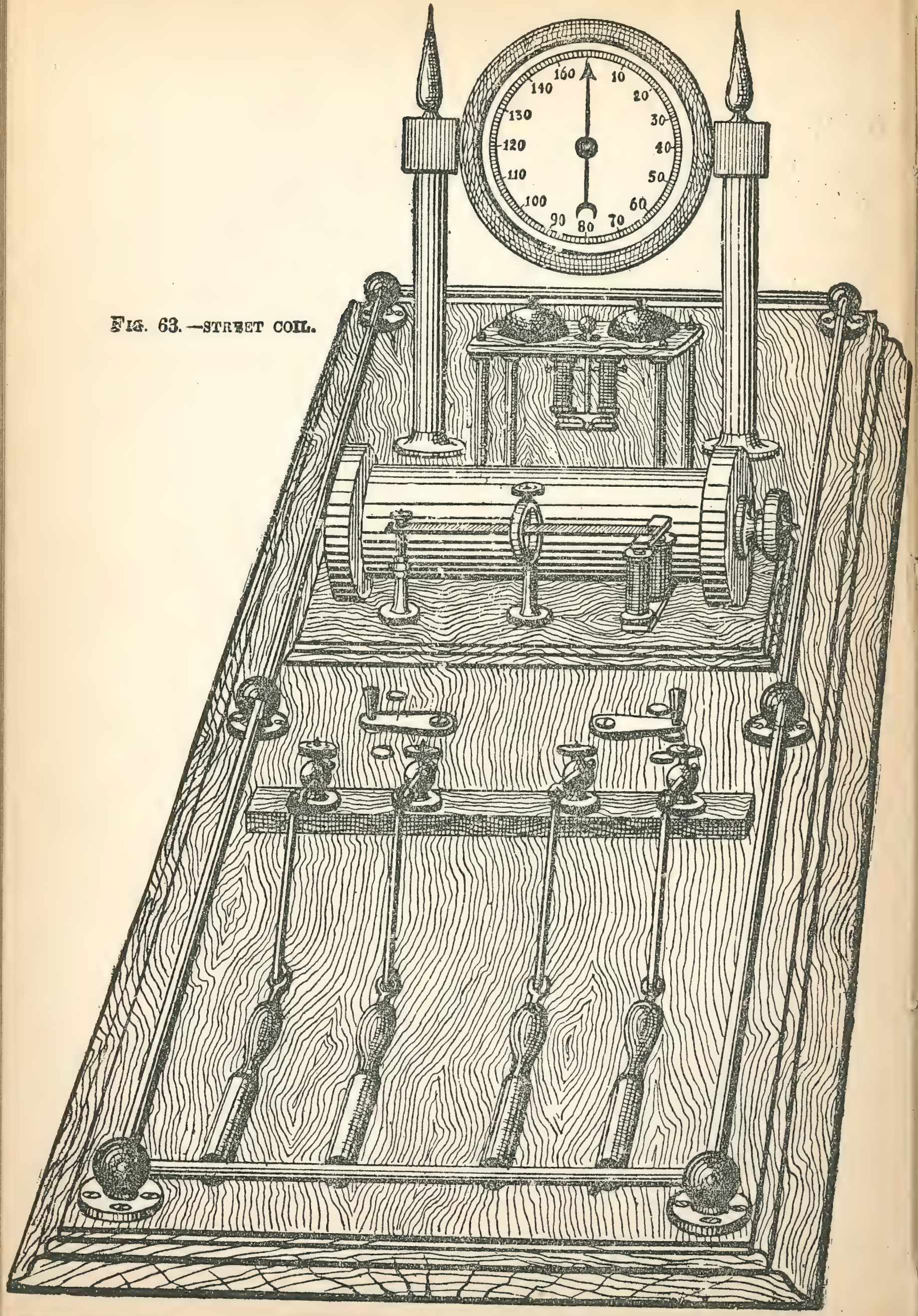


FIG. 63.—STREET COIL.

The bobbin of the coil is similar in construction to the bath coil described on p. 60, except that it is wound only with a primary and secondary winding. More space must also be left for the tube to work in, as a fine piece of gut is attached to the end for working the needle of the indicating dial. This gut passes through the left-hand cheek of the bobbin, through the base, up the left-hand brass pillar of dial, round drum of needle three times, and then down the right-hand pillar, inside which is a small lead weight that is attached to the end of the gut. At the corners, where the gut makes a turn at right angles, the edges of the metal or wood must be rounded off, and it may be necessary in some cases to fix small pulleys before the gut is got to run freely. When properly fitted, as the regulating tube (the knob of which is seen to the right of the bobbin) is drawn out more and more, so the needle on the dial will indicate a greater strength, while when pushed back the needle returns, impelled by the weight on the end of the thin gut cord. The contact-breaker is fixed on the same base as the bobbin, and consists of the supporting brass pillar seen on the left, which carries the thin brass spring that has affixed to the end of it the soft-iron armature. Below the armature are the two magnet bobbins in series with the primary winding of the coil. Half-way between the supporting pillar and these magnet coils is the brass standard carrying the contact-breaker screw, this screw being fixed in the top of the ring, through which passes the contact-spring carrying the soft-iron armature. Both the supporting pillar and the contact-pillar are secured by stout screws passed through the base from beneath. The two magnet cores are fastened to a strip of soft iron, which is in turn secured by two screws to the base.

Just in front of the contact-breaker, and at equal distances from the two centre pillars of the brass rail, are two switches, having three contacts each. The switch on the right controls the current to the right pair of handles, and that on the left to the left pair. Of the three contacts, the first is for the primary, the second for the secondary current, and the third is an off-block. The contacts and levers are fixed directly on to the base, and should be of brass, the different parts being somewhat heavily proportioned.

In front of the two switches are four heavy brass terminals forming the connection for the handles. These terminals are supported off the base by a strip of polished mahogany, and are bolted through this and the base. It is very important that these terminals are of solid design and firmly fixed, as great strain is liable to be thrown on them by persons pulling at the handles. The connections to the handles are likewise made by brass rods a little over $\frac{1}{8}$ inch thick, for, if flexible cords were used, they would continually be being broken by persons pulling or jerking the handles. These connections are in three pieces, fastened together by making loops at the end of each piece. The handles themselves consist of pieces of brass tube (plated if desired) with polished mahogany end-pieces, through holes in the centre of which pass the connecting rods.

The connections to the different parts are not shown in the drawing; but from what has already been said and illustrated in regard to previous coils, the reader, if he has studied these, will have no difficulty in tracing them out for himself. It must be remembered there are primary and secondary windings, that the contact-breaker is in series with the primary, and that the two pairs of handles are connected in parallel.

As regards the dimensions of the different parts of the coil, these, of course, can be anything the constructor desires. A very good size is to make the dial 12 inches in diameter, and the rest of the coil proportionate thereto. The battery employed for working such a coil is a four-cell bichromate, which would be placed in the body of the truck supporting the coil.

CHAPTER IV.

ACCESSORY APPLIANCES FOR, AND THE APPLICATION OF MEDICAL COILS.

In the application of electricity to the cure, alleviation, or diagnosis of disease, there are three kinds of currents employed. First, currents from batteries applied direct, or Galvanisation; second, induced electric currents, or Faradisation; and third, static electricity, or Franklinisation. When the electric current is employed for the destruction of the tissues of the body by decomposition the application is known as electrolysis; while electro-cautery is the process of removing or destroying diseased portions of the body by metallic points, rendered white hot by the passage of electric currents.

For Galvanisation, from 20 to 40 cells connected in series are required, and in addition, a collector for connecting on more or less cells, a current-reverser for changing the direction of the current, and a milliampère meter for indicating the strength of the current passing through the patient. Rheostats are sometimes employed in Galvanisation where there is no collector, in order to vary the strength of the electric current by inserting more or less resistance in the circuit.

For Faradisation, a medical coil is required giving primary and secondary induced currents, the coil being fitted with suitable means both for regulating the strength of the current and the rapidity of the interruptions. A suitable battery, capable of working the coil for an hour or so without running down, must also be provided.

For Franklinisation, some form of electro-static machine such as a Wimshurst, Holtz, &c., will be necessary.

In electrolysis a battery of one or two cells is required, and special electrodes according to the nature of the disease. Usually these electrodes consist of needles, insulated except at their points, which are pushed home to the centre of the affected place. Double needles are employed or one needle (negative) only, the patient holding the positive electrode in his or her hand.

The whole of the current being confined at one electrode to the point of a needle, the chemical action of the electric current is concentrated at that point, and the surrounding tissues, such as the root of a tumour, decomposed.

For electro-cautery a battery that will give a powerful current and not run down is absolutely necessary. A strong current is required to render white hot the metallic burners, and it is, of course, important that the burners are maintained at the same heat during the whole of the operation. A large number of different burners are made for cutting in this and that direction, and to suit the different forms of diseased growths.

For the greater convenience of medical men all the different apparatus necessary for the application of the Galvanic and Faradaic currents are frequently combined together in one cabinet, a form of which is shown in Fig. 64. In the cupboard at the bottom are contained the 40 cells for Galvanisation, and also the two cells for working the medical coil. This coil is to be seen on the left-hand side of the desk-shaped part at the top, while in a similar place on the right-hand side is the milliampère meter. On an inclined base in the centre of the cabinet are fixed the collectors, current-reversers and various switches controlling the working of the induction coil and the primary and secondary currents. The top part of the cabinet is fitted with a glass front, which lets down and locks to prevent its being

tampered with. The two terminals for the connecting cords to the electrodes are in front of the inclined base.

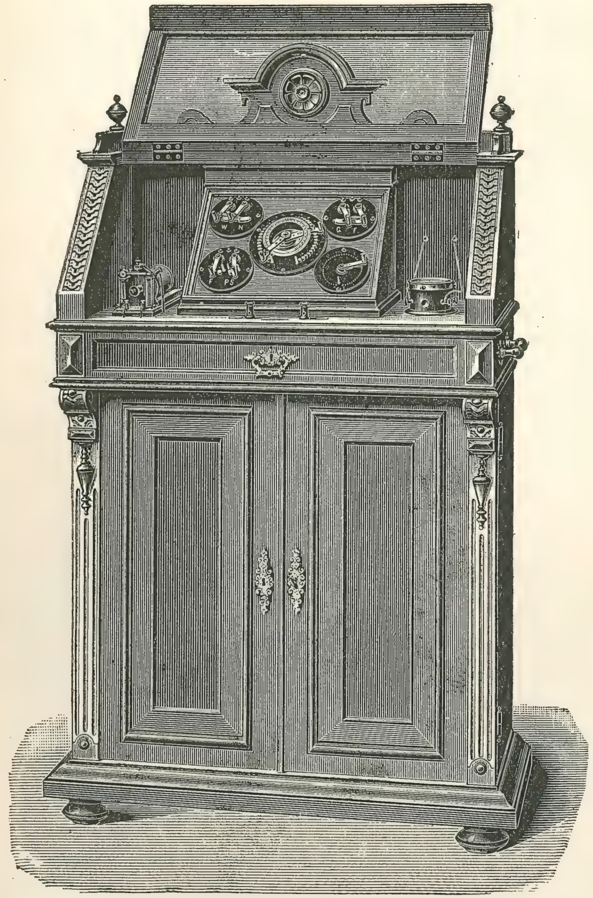


FIG. 64.—ELECTRO-MEDICAL CABINET.

Conducting Cords and Electrodes.

The conducting cords, or rheophores as they are also frequently called, are the wires connecting the terminals of the instrument with the electrodes. They are, of course, two in number, one being required for each electrode. The ordinary conducting cords, as used for Faradisation, consist of tinsel cord served with one to two layers of cotton, and then braided usually in fancy colours, the ends of the cords being provided with special metal tips for convenience in inserting in the instrument terminals and electrodes. The cords vary in length from one to three yards. For Galvanisation the

FIG. 65.

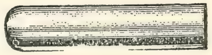


FIG. 66.

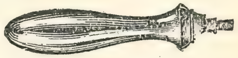


FIG. 67.

ELECTRODES.

conducting cords used are generally more expensive, being insulated with gutta-percha and more heavily braided. It will be found more convenient to have the two conducting cords of different colours, so that the positive and negative electrodes can easily be distinguished. Fig. 65 shows the form of cord usually employed.

Of electrodes there are, of course, a great variety of different shapes and forms, there being special electrodes designed for use on nearly every part of the body. It may be as well to mention, perhaps, for the benefit of those not conversant with electrical terms, that an electrode is the plate, ball, sponge, or other enlargement at the end of the conducting cord by means of which the current is applied to

the body. In applying the current, two electrodes are necessary, the one being attached to the positive conducting cord, and the other to the negative, the two electrodes being known as the positive and negative electrodes respectively.

The most usual electrode employed is, of course, the handle, as shown in Fig. 66. This is usually of brass, plated, and in the better forms of coils arranged to screw on to the wooden handle, Fig. 67. This allows the physician to hold the handles in the patient's hands without himself receiving a shock, and thus reducing the strength of the current that is being applied.

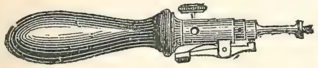


FIG. 68.

FIG. 70.

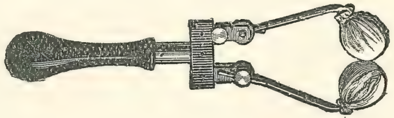


FIG. 9.

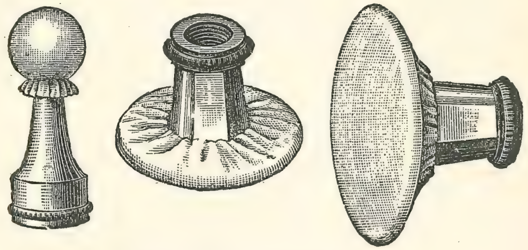
ELECTRODES.

Fig. 68 shows a wooden handle fitted with a switch for interrupting the circuit. The metal handle, as in Fig. 66, or any other electrode, screws on to the metal extension of the handle, and the physician, holding the wooden part of the handle in his right hand, can break the circuit at will by pressing with his finger the button seen underneath.

Fig. 69 shows a double pole electrode, for use when it is required to confine the current that is being applied to a small area. The two arms carrying the electrodes are fixed on swivels, so that the distance between them can be varied at will.

Fig. 70 shows an improved form of electrode for holding a sponge. The sponge is pressed into the end of the metal tube, and, expanding through the three holes in the side, is thus retained in its proper position.

Figs. 71, 72 and 73 show three of the more common shapes of electrodes used, and all are adapted to fit on the different forms of handles just described. These electrodes consist of tin, brass or carbon plates, covered either with flannel or



FIGS. 71, 72, 73.—ELECTRODES.

chamois-leather. They must be wetted for application, and the flannel or leather after much use must be renewed, as they rapidly pick up the dirt. The metal plates also quickly oxidise, and must, therefore, before new flannel or leather is put on, be cleaned with emery cloth or by scraping with a knife. Electrodes with flexible gelatine plates that adhere to the skin are now being much used. Electrodes of

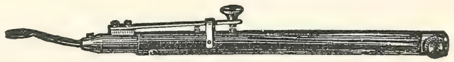
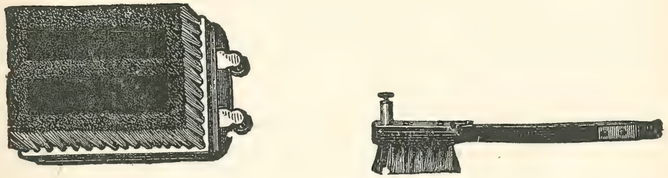


FIG. 74.—EYE ELECTRODE.

common metal, since they oxidise, must not be placed on the mucous membrane unless connected to the negative pole.

Fig. 74 shows an electrode for the muscles of the eye, the handles being provided with a switch, so that the current can be at once switched on by a slight pressure of the finger.

Brushes consisting of bristles of very fine wire are used for exciting the nerves of the skin. They are connected to the conducting cords and passed lightly over the surface of the skin. Fig. 75 shows a single-pole brush, and Fig. 76 a



FIGS. 75, 76.—BRUSH ELECTRODES.

double-pole one, for local electrisation. All the brushes are provided with wooden handles, so that the physician can apply the electrode to the patient without himself receiving a portion of the current.

Fig. 77 shows a roller or wheel electrode, by employing

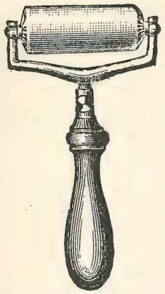


FIG. 77.—ROLLER ELECTRODE.

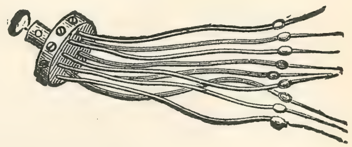


FIG. 78.—NEEDLE ELECTRODE.

which the place of application can more conveniently and rapidly be changed. They are also used for combining massage with the application of electricity.

Fig. 78 shows an electrode composed of nine needles for electrolysis. These are employed for destroying the roots of hairs, tumours, nævi, &c., by the decomposing action of the electric current. The needles are composed of gold or platinum, insulated throughout their length, except at the very point, by a special enamel or a coating of vulcanised rubber.

The object of having so many needles on the one terminal is because should one needle fail another can rapidly be inserted in its place.

Galvanometers and Milliampère-meters.

Fig. 79 shows a form of galvanometer much used for electro-medical purposes. It consists of a very delicately

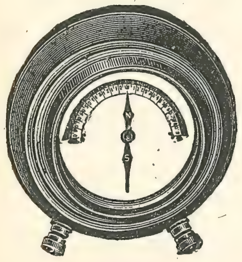


FIG. 79.—GALVANOMETER.

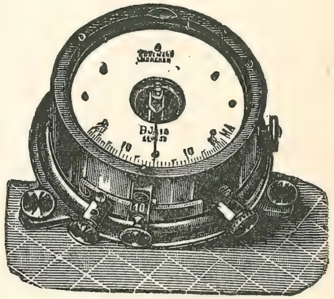


FIG. 80.—MILLIAMPÈRE-METER.

suspended needle, round which is wound a coil of fine wire, the needle being deflected by the passage of an electric current, and indicating the amount of deflection on the dial. For medical purposes, of course, these galvanometers require to be very sensitive owing to the feeble currents employed. To obtain sensitiveness in a galvanometer it is necessary to have the needle very delicately poised, and to wind the bobbin with a large number of turns of very fine wire. The galvanometer is intended more for indicating the pressure of

a current, while the milliampère-meter reads off on the dial the exact value of the current passing in milliampères, or thousandth parts of an ampère. The internal construction of both is much the same, the difference being that the scale of the latter has been graduated while currents of known strengths have been passing through it. A form of the milliampère-meter is shown in Fig. 80.

Collectors.

Collectors are either single or double, according to whether they have one or two collecting arms. A form of

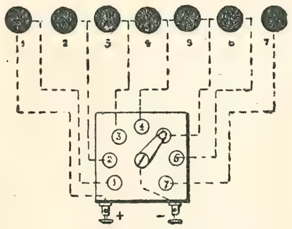


FIG. 81.—SIMPLE FORM OF COLLECTOR.

the single collector with its connections to the cells is shown in Fig. 81. It consists of a number of contacts, one for each cell, arranged in a circle on a wood or ebonite base, in the centre of which is a brass arm arranged to work on these contacts. The connections are run as shown by the dotted lines, and thus, as the arm is moved round in the direction of the arrow, more and more cells are connected on to the terminals + and −. Double collectors have two contact-arms and are more convenient, as they allow any portion of the battery to be included, as only the cells between the two arms are connected on to the terminals. Thus, if one arm is on contact 5, say, and the other on contact 15, only the cells between 5 and 15 inclusive would be in circuit. A small number of cells can therefore be selected from any portion of the battery. The connections of the double collector are somewhat different.

Current Reversers.

The form of current reverser chiefly employed with medical coils is shown with its connections in Fig. 82. It consists, it will be seen, of two switch-arms bolted together by a piece of ebonite, below which are three contact-studs

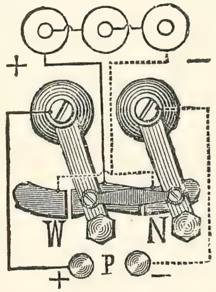


Fig. 82.—CURRENT-REVERSER.

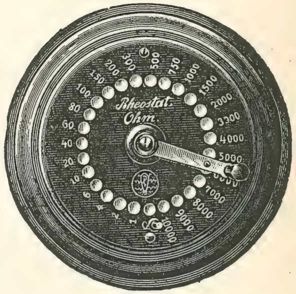


Fig. 83.—METALLIC RESISTANCE.

connected as shown. When the switch is in the position shown in the figure, the left-hand terminal is + and the right −, but if moved to the opposite side the left becomes − and the right +.

Rheostats.

Rheostats or resistances, employed for electro-medical purposes, are either metal, liquid or carbon. A form of the metal resistance is shown in Fig. 83, having 27 contacts and giving various resistances from 1 to 1000 ohms. The resistances are connected to the contacts so that as the arm is

moved to each contact resistance to the amount marked is thrown into circuit.

Perhaps the most simple form of resistance is the liquid resistance as shown in Fig. 84. This consists of a glass tube fixed on to a wood base by means of a brass cap, on which is fastened the one terminal Another brass cap is fastened to the top of the tube, through which passes an adjustable brass rod. A second terminal is attached to this top cap and the tube three-fourths filled with water. If this liquid resistance or water regulator is connected in circuit by means of the two terminals, it follows that the strength of the current passing will be diminished as the brass rod is withdrawn, owing to the length of the column of water being increased. On the other hand less resistance is in circuit as the brass rod is pushed down, and the current therefore increases.

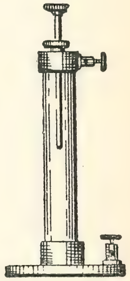


Fig. 84.—LIQUID RESISTANCE.

CHAPTER V.

SPARK COILS.

SPARK coils is a name applied to all induction coils designed and constructed to produce large sparks at the secondary terminals, as distinguished from those coils intended merely for administering shocks for amusement or medical purposes, and known as shock or medical coils.

Although the difference between spark and medical coils may be said to be mainly in the size, strength and higher insulation of the different parts, yet very much more care must be taken with the construction of the former, certain methods of fixing and insulating different portions that are suitable for medical being quite inadmissible in a spark coil. The chief point to which increased attention must be directed is, of course, the insulation of primary and secondary windings, and more particularly the latter.

The very high tension of the secondary current enabling it to spark great distances, necessitates the utmost precaution being taken both in the winding and insulation of the secondary coil. Should the spark find an easier path, or path of less resistance, than between the two ends of the secondary, whether it be from layer to layer of secondary or secondary to primary, it will assuredly take it, and, once taken, it will always follow it in preference if the ends of the secondary are separated far apart.

A break-down in the insulation of the coil, if not rendering it utterly useless, always very considerably reduces its sparking distance, and as such break-downs may occur on the first trial of the coil, and generally necessitate unwinding and rewinding, it will be found advisable not to grudge a few extra hours during the construction, in order to take all possible precautions.

Unquestionably the secondary winding is the part of the coil requiring the most attention, and in very large coils so great is the tendency of the discharge to break down the intervening insulation between the layers, that some special method of arranging the secondary, such as sectional winding, has to be adopted.

With small spark coils, however—i. e. those giving under $1\frac{1}{2}$-inch sparks—it is very doubtful, taking all things into consideration, if anything is to be gained by sectional winding, as with reasonable care there is little difficulty in insulating the different portions so as to prevent a breakdown in the insulation.

Our object as regards the secondary is to get on as many turns as possible, consistent with efficient insulation and not getting too far from the primary. Every turn of wire adds to the E.M.F. of the induced current, and as the E.M.F. is augmented, so, of course, the length of spark is increased. Nos. 38 and 40 B.W.G. best silk-covered copper wire are the most suitable sizes for small spark coils; Nos. 36 and 34 for large ones. The finer the wire the more turns can be got on and the longer the spark, while if a short thick spark is desired a thick wire, such as No. 34, must be employed.

In Chapter II. we pointed out the extra precautions to be taken with regard to the different parts of a spark coil, so we will now proceed to describe in detail one or two different sized coils wound both in the ordinary manner and sectionally.

An Inch Spark Coil.

Fig. 85, half full size, and Fig. 86, one-third full size, show in side elevation and end elevation an inch spark

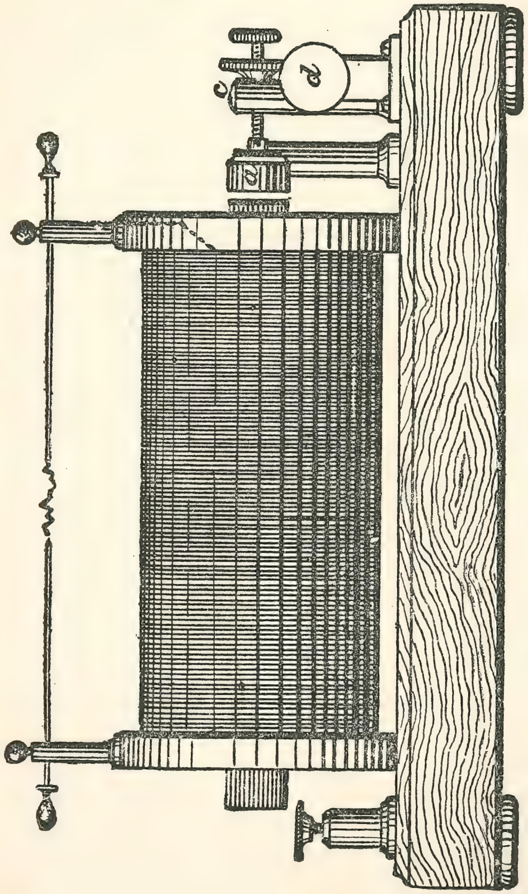


FIG. 85.—AN INCH SPARK COIL (scale one-half).

coil complete with commutator. Referring to these figures, the bobbin ends are of ebonite, 3 inches in diameter and $\frac{3}{8}$ inch thick, the extreme length of the bobbin being $6\frac{1}{2}$ inches. The iron core is $7\frac{1}{8}$ inches long and slightly under $\frac{3}{4}$ inch in diameter. The body of the bobbin is made up of several layers of paraffin paper, as previously described, into the centre of which is forced the iron core of No. 22 charcoal iron wire. The bobbin having been carefully prepared, the

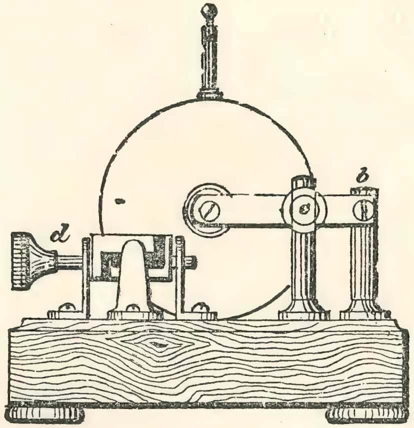


FIG. 86.—AN INCH SPARK COIL (scale one-third).

primary is next wound on, this winding consisting of two layers of No. 16 silk-covered copper wire.

The primary being finished, it must be carefully tested with a battery of two or three cells to see that it is correctly wound, and if the magnetism in the core seems sufficiently powerful, the surface of the primary can be prepared for the secondary.

For the secondary we shall require $1\frac{1}{4}$ lb. of No. 38 best silk-covered copper wire. This should give us slightly over 1-inch spark with three quart Bunsen cells, and if much over we may consider that we have been fairly successful in our winding. This secondary must be wound on, layer upon layer, with a wrapping of thick, well-paraffined note-paper between each layer, and the different layers must not be run up nearer than $\frac{1}{2}$ inch from the bobbin ends. The inside end of the secondary must be brought up inside the right-hand bobbin-cheek, as shown by the dotted lines in Fig. 85. This is done by drilling a hole in an oblique direction, and then another down from the top to meet it. The inside end can then, previous to winding, be worked through this hole, and this hole afterwards run in with paraffin

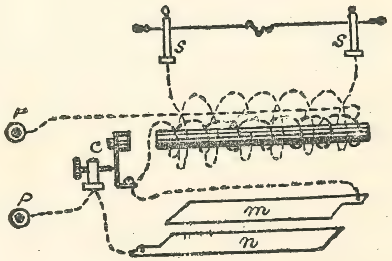


FIG. 87.—CONNECTIONS OF SPARK COIL WITHOUT COMMUTATOR.

wax. After the last layer of secondary has been wound, six wrappings of well-paraffined, thick note-paper must be put on, and the whole well basted with wax, finishing with a layer of black-ribbed paper.

The contact-breaker consists of the brass pillar *h*, carrying the hammer *a*, and contact-spring, while behind this is the pillar *c*, carrying the contact-screw. The height of these pillars is $1\frac{3}{4}$ inch, and the contact-spring is $2\frac{7}{8}$ inches long by $\frac{1}{2}$ inch wide. Two substantial terminals are fitted on the left-hand side of the base for the primary connections, while the secondary terminals are fixed on top of the bobbin-cheeks, as shown. Two thin brass rods, fitted at one end with ebonite

knobs, slide in the holes of these terminals to form the discharger.

The commutator, or current-reverser *d*, is fixed at the right-hand end of the base, and consists of an ebonite cylinder, fitted on each side with two brass contact-plates, as shown in Fig. 86, these two plates being in contact with the uprights supporting the cylinder, which uprights are in connection with the two poles of the battery. At each side of the cylinder is a contact-spring, one spring being connected to the outside end, and the other to the inside of the primary coil through the contact-breaker. It will thus be seen that if the cylinder is turned half-way round, the direction of the

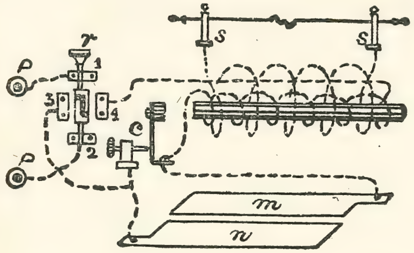


FIG. 88.—CONNECTIONS OF SPARK COIL WITH COMMUTATOR.

current in the primary circuit will be reversed, while if turned only a quarter of a revolution, the circuit is interrupted. The connections of the coil, with and without a commutator, are shown in Figs. 88 and 87, which also show the method of connecting up the condenser. Fig. 88 is the one with the commutator. In both the figures PP are the primary terminals, *s s* the secondary, and *m* and *n* the two sheets of the condenser.

The base of the coil, which is of polished mahogany, is $14\frac{1}{2}$ inches long by 6 inches wide, and $1\frac{3}{4}$ inch deep, not including the feet. It is made of $\frac{1}{2}$-inch wood, the bottom being removable for easy access to the condenser. The condenser, which occupies very nearly the whole of the inside of the base, consists of 40 sheets of tinfoil, 6 inches by 4 inches, put together as described in Chapter II. It must then be slipped inside the wood base (the connections to the different parts of the coil having, of course, first been made), and connected up as shown in Figs. 87 and 88, taking care the ends of the condenser are well apart, and to well soak the inside of the top part of the base with paraffin-wax.

The following are the dimensions for the different parts of a $\frac{1}{2}$-inch and $\frac{3}{8}$-inch spark coil, of a similar construction to the one just described:—

	inches.	inches.
Length of spark	$\frac{1}{2}$	$\frac{3}{8}$
Size of bobbin ends..	$2\frac{1}{2} \times \frac{5}{16}$	$2\frac{1}{8} \times \frac{1}{4}$
Length of bobbin	$5\frac{1}{2}$	4
Length and diameter of core ..	$6 \times \frac{5}{8}$	$4\frac{1}{2} \times \frac{7}{16}$
Size of base	$9 \times 5 \times 2$	$7\frac{1}{4} \times 3\frac{3}{4} + 1\frac{1}{2}$
Size of tinfoil sheets	$5\frac{1}{2} \times 3\frac{1}{4}$	4×2
Number of tinfoil sheets	40	36
Size of paper sheets	$6\frac{1}{2} \times 4\frac{1}{4}$	5×3
Primary coil	No. 18	No. 18
Secondary coil..	No. 40, 1 lb.	No. 40, $\frac{3}{4}$ lb.

Sectionally-Wound Coils.

Sectional winding, as applied to spark coils, consists in winding the secondary, not in a succession of continuous layers from bobbin-cheek to bobbin-cheek, but in dividing it up into a number of sections or divisions, which sections are afterwards joined in series. The object of so dividing up the secondary is because that with the wire thus distributed, the ends and those portions of the winding between which there exists a very high difference of potential, are either placed very far apart, or else separated by a thin disc of some material having great insulating properties. In large spark coils, with the enormous difference of potential that exists at

the ends of the secondary winding, there is a tendency to discharge in all directions—one portion of the secondary to another, secondary to primary, and, in fact, any part where the insulation is weak—so that to get the best results, or, indeed, to get any results worth speaking of, some method of sectional winding must be adopted.

Sectionally-winding induction coils appear to have been first introduced by Messrs. Siemens and Halske, of Berlin, who exhibited a large coil with the secondary wound in sections at the Great Exhibition of 1851, which gave what were then considered remarkably good results. The tube and divisions for the secondary were turned up out of a solid block of ebonite, from the centre of which the primary could easily be withdrawn and replaced. This method of construction, apart from its expense, is not one that will recommend itself to those desirous of constructing large spark coils; but in the *English Mechanic* of August 5, 1870, a method of constructing a sectionally-wound coil giving 8-inch sparks was described by "Inductorium," in which the divisions (there being 90 sections) consisted of separate ebonite discs slipped on one by one over the ebonite tube, with distance pieces or rings between. This method, or rather a modification of it, as subsequently suggested by "Inductorium," in which discs of several layers of paraffined paper are substituted for the ebonite ones, the writer has found, after experimenting with nearly every other method of winding, to give the best results, and one that enables any one possessed with an average amount of patience to construct a really powerful and efficient coil at a comparatively small outlay.

Figs. 89, 90, 91, 92, 93, 94 and 95 are diagrams illustrating the manner in which sectionally-constructed coils are wound. In Figs. 89, 90, 91 and 92 the whole coil is shown in section, the black portions being the ebonite ends and divisions slipped on the central iron core, round which is shown, by the dotted lines, the secondary winding. Figs. 93, 94 and 95 are sections of the top half of the coils, only showing both the primary winding P, and the secondary S. Here the successive layers are shown, and to make the explanation clearer, the bottom halves of the windings are omitted.

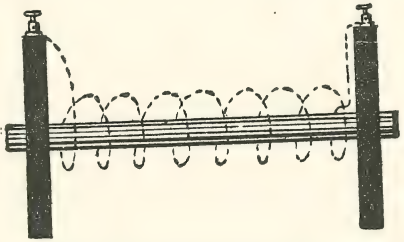


FIG. 89.—ORDINARY METHOD OF WINDING.

Referring to Fig. 89, which represents the ordinary method of winding without any sections at all, the secondary being in a succession of continuous layers from bobbin-

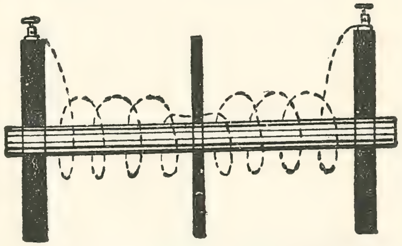


FIG. 90.—COIL WOUND IN TWO SECTIONS.

cheek to bobbin-cheek, it will be seen that one of the greatest disadvantages of this method is that the inside end must pass in succession each layer of wire as it rises to the terminal on the top of the right-hand bobbin-cheek. This will, perhaps, be better seen from Fig. 93, which shows

the same method of winding but figured in a different manner. Referring to this figure, the thick dotted lines are the two layers of the primary P, above which are the thin ones S, representing the different layers of secondary. The

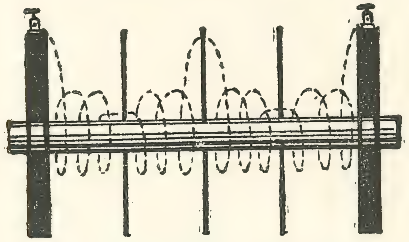


FIG. 91.—COIL WOUND IN FOUR SECTIONS.

passing of the successive layers by the inside end is clearly shown here, and as it approaches the outside layers the greater does the difference of potential between this end of the winding and the layers become. There is, therefore, a

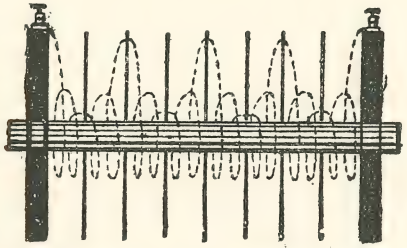


FIG. 92.—COIL WOUND IN EIGHT SECTIONS.

great tendency for the insulation to break down at this part of the coil, with the result that the moment such an occurrence takes place the coil is ruined. Apart from this, there being also a great difference of potential between the ends of these long layers, there is a tendency to discharge from layer to layer, and though there are ways in which the insulation can be greatly increased at these points, and the probability of a break-down be reduced to a minimum, yet the best of coils so wound cannot in any way compare

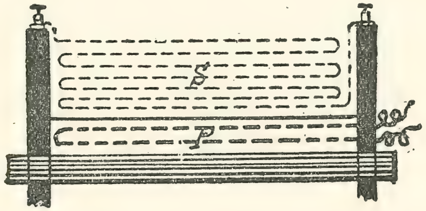


FIG. 93.—ORDINARY METHOD OF WINDING.

with one in which the secondary has been sectionally distributed.

The simplest method of sectional winding is shown in Fig. 90, another view of the same method being shown in Fig. 94. In this method the space for the secondary is

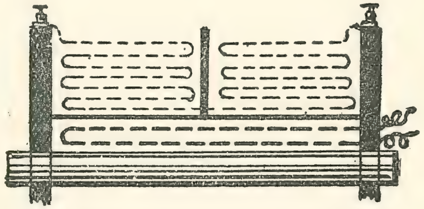


FIG. 94.—COIL WOUND IN TWO SECTIONS.

divided into two halves by an ebonite disc $\frac{1}{16}$ inch to $\frac{1}{8}$ inch thick, this disc fitting tight on the ebonite tube or other material forming the insulating medium between the primary and secondary. The secondary is then wound on in two portions, one portion being wound in each division.

The inside ends of these two portions are joined together, so that the two free ends of the winding are both *outside* ends, and finish off quite close to the terminals to which they are to be connected. We have now no inside ends passing layer after layer of wire, and the greatest tendency to spark from one part of the winding to the other is between the ends of the layers butting on to the ebonite division disc. As this is a substantial disc of high insulating material, the insulation is perfectly safe. The tendency to spark through this disc is greatest, of course, at the two top layers, and though the spark cannot pass through the disc yet it might jump over the top; so to obviate this the ebonite disc is carried up

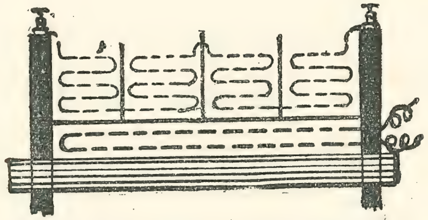


FIG. 95.—COIL WOUND IN FOUR SECTIONS.

higher than the bobbin-cheeks, so as to increase the distance the spark would have to travel. In winding the secondary of a coil constructed on this method, the end of the wire is passed through a small hole in the bottom of the dividing disc, and the one half of the coil wound with half of the quantity of wire that is going to be put on. The coil is then turned round, and a joint made with the end of the remaining half of the wire on to the inside end projecting through the disc. This portion of the wire is then wound on, the outside end finishing off at the other terminal, as in Fig. 90. It is important to remember that before winding on the second half of the secondary the bobbin must be turned end for end: otherwise the two windings will oppose one another.

Fig. 91 shows a coil wound in four sections, and Fig. 95 is another view of the same method. The division pieces are ebonite discs fitted on the ebonite tube containing the primary. The secondary is divided into four portions, and we have thus less chance of a break-down in any one division; while, moreover, should any one division break down, the effects on the sparking of the coil are not so very disastrous. The connections between the divisions are, it will be seen, made alternately at the top and bottom of the dividing discs. It is in reality like two coils wound, as shown in Fig. 90, placed end to end, and connected in series. In winding, the division at one end is first wound, the inside end being slipped through a hole on the bottom of the dividing disc, to which end the beginning of the second division is connected, and, the coil being first turned round, this second division is then filled. The same process is carried out with the other two divisions, the two ends of the centre divisions (which are outside ends) being afterwards joined together either across the top of the disc or through a hole near the edge.

Fig. 92 shows a sectionally-wound coil having eight divisions or sections. The process of winding is, of course, similar to that just described, the difference being that there are double the number of divisions, and consequently just half the amount of wire in each division for a coil of the same size. There must always be an odd number of division pieces, so as to make an even number of sections, and thus allow the ends of the two outside sections to finish on the outside close to the terminals. As the number of divisions or sections is increased, so the thickness of the division disc can be somewhat reduced.

A 2-inch Spark Coil.

Figs. 96 and 97 show a 2-inch spark coil, the secondary of which is wound in two sections, as shown diagramatically in Figs. 90 and 94. Fig. 96 is a side elevation, while Fig. 97 is an elevation from the contact-breaker end. The base, which is of polished walnut or mahogany, is 12 inches long by $7\frac{1}{2}$ inches wide, the height from the top of the base to

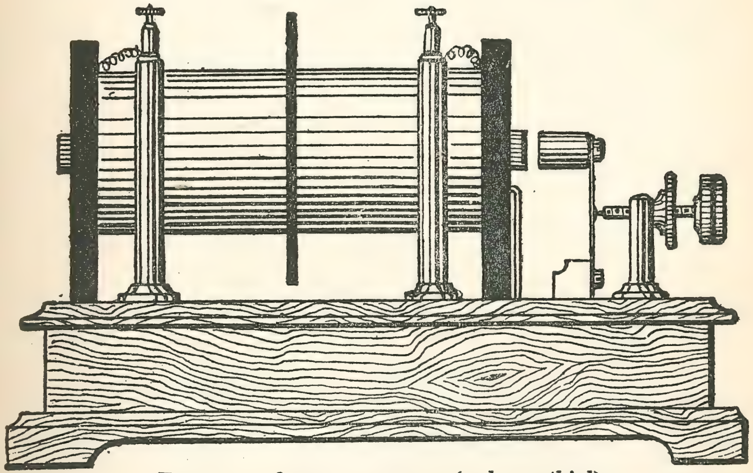


FIG. 96.—A 2-INCH SPARK COIL (scale one-third).

the bottom of the feet being $3\frac{1}{4}$ inches. The base is hollow, and contains the condenser, after the manner described for the 1-inch spark coil, previously described. The two end pieces, or bobbin-cheeks, are of ebonite and square in form, being 4 inches high by $2\frac{3}{4}$ inches wide by $\frac{3}{8}$ inch thick. The iron core passes through the centre of these cheeks vertically, but slightly above the centre horizontally. The distance between the inside faces of the bobbin-cheek is $6\frac{1}{2}$ inches.

After the primary (which consists of two layers of No. 14 B.W.G. silk-covered wire) has been wound, the centre ebonite division disc, which is $4\frac{1}{2}$ inches in diameter by $\frac{1}{8}$ inch thick, is placed centrally on the primary winding, and the ebonite end-pieces or bobbin-cheeks slipped on. The secondary, which consists of $2\frac{1}{2}$ lbs. No. 36 silk-covered wire, is then wound on as described with reference to Fig. 90, there being 1 lb. in each division. The outside ends of the secondary are then connected to the terminals of the ebonite discharging pillars, the height of which is 5 inches. A

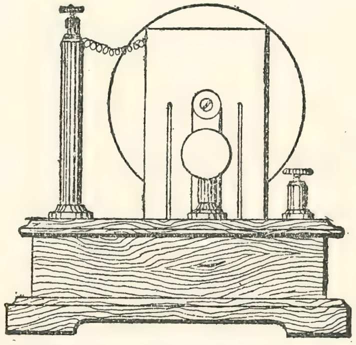


FIG. 97.—A 2-INCH SPARK COIL.

wrapping of thin sheet ebonite is then wrapped round the outside of each division, both to improve the appearance of the coil and protect the secondary against mechanical injury. The contact-breaker, which is of a very substantial character (to scale one-third full size in illustration), is fixed at the right-hand end of the base. The condenser consists of 60 sheets of tinfoil, 6 inches by 6 inches, put together and connected to the contact-breaker as described in Chapter II. The two primary terminals are fixed at the right-hand end of the base on one side of the contact-breaker.

A 12-inch Spark Coil.

We will now pass on to the construction of a somewhat larger spark coil, viz. one giving 12-inch sparks. There are probably few persons of an electrical turn of mind who have not some time or other wished to be the possessor of a large coil, with which so many interesting and instructive experiments can be performed. To purchase a coil of this size would cost something like 50*l.*, thus putting it beyond the reach of many; but since those with a little spare time at their disposal and a reasonable amount of patience can construct one equally as efficient for about one-fourth that price, the objection on the score of expense need no longer exist.

In the back volumes of the *English Mechanic* will be found a description of a large number of spark coils, giving 4-inch to 10-inch sparks, constructed on a similar plan with great success by several readers of that journal, notably those of Mr. J. Brown, of Belfast (*English Mechanic*, Feb. 27, 1880); Mr. E. Baugh (Jan. 4, 1884); Mr. Higgs (Feb. 11, 1887); and Mr. T. H. Muras (Oct. 7, 1892.).

The main requirements necessary for success are patience and a determination to construct each part thoroughly. Never leave one portion until quite satisfied that every precaution has been taken to render it as perfect as it is in your power to make it. Remember that even one little point passed over in a slovenly manner may be the cause of a complete failure, and that it is an easy matter to alter certain parts during construction, while, when finished, it is often impossible to do so without pulling the whole coil to pieces. If these points, together with the fact that the secondary discharge is always endeavouring to find out a weak point in the insulation, are carefully borne in mind, there is very little reason to doubt a successful issue and the ultimate possession of a really serviceable coil.

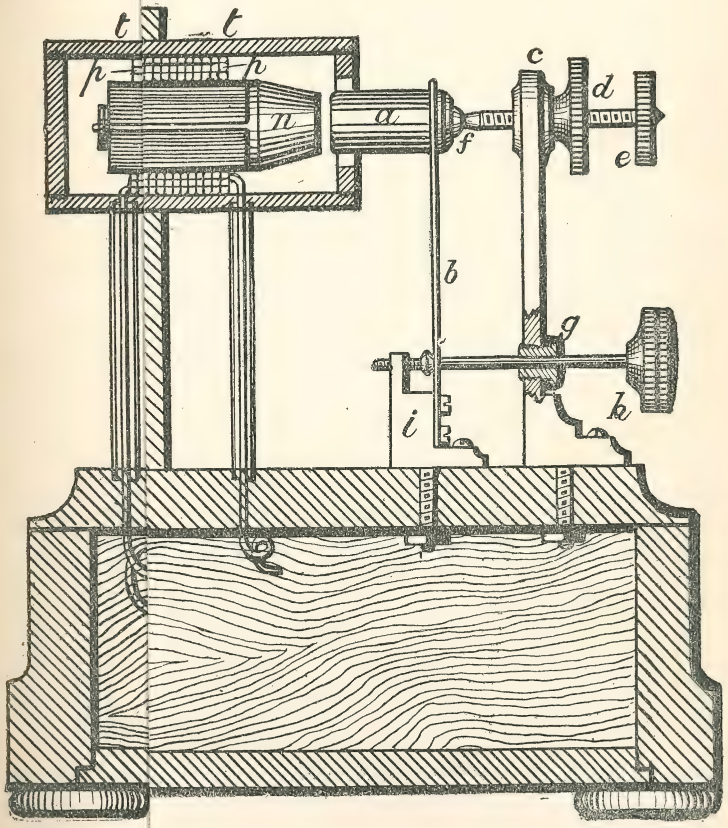
Fig. 98 shows the coil in section, one-third full size. The primary terminals, commutator, condenser, discharger and secondary terminals are omitted in order to make the illustration clearer. Referring to this figure, *m* is the iron core and *n* an extension of one pole for the purpose of working the contact-breaker. The primary winding is marked *p*, over which is the ebonite insulating tube *t*, separating the primary from the secondary. *x*, *x*, are the two ebonite cheeks of the bobbin, which is supported up from the base of the coil by the polished wood supports *o*, *o*. The secondary winding, *s*, is wound on in 96 sections of an outside thickness of each section of $\frac{1}{8}$ of an inch. *w* is the base, which can be of polished walnut, teak, or mahogany, as desired, and has at the right-hand end the contact-breaker, which latter is of Apps' improved form.

In constructing the coil the first portion to be made is:—

The Core.

This consists of a number of lengths of highly annealed charcoal iron wire, No. 22 gauge, which, when made into a compact bundle, forms a tightly packed core 19 inches long by $1\frac{1}{2}$ inch in diameter. Through the centre of the core passes a $\frac{1}{8}$-inch soft iron rod, carrying at one end the iron extension piece, *n*, and having at the other end a nut which, when screwed up, clamps the extension piece firmly to the iron core. The iron wires are best formed into a bundle by procuring a piece of metal tube, the inside diameter of which is equal to the required outside diameter of the iron core, and then forcing the wires into this until packed quite tight. The tube is then gradually slipped off, at the same time binding round the core, at intervals of every 3 inches, some thin binding wire, until the tube is completely withdrawn and the bundle left complete. The core should then be immersed in melted paraffin wax and kept at an even

[To face page 108.



[To face page 108.

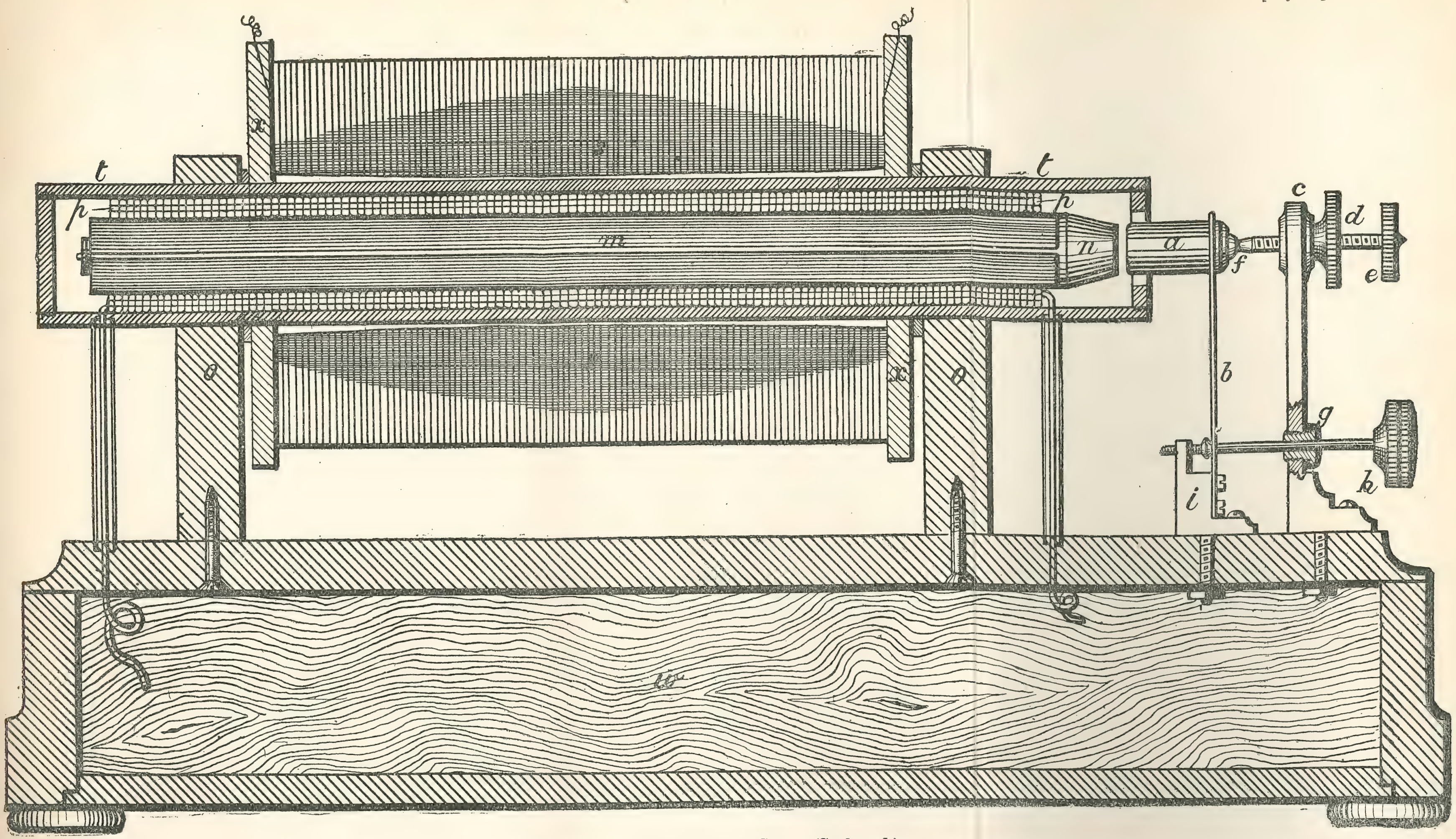


FIG. 98.—A 12-INCH SPARK COIL. (Scale $\frac{1}{3}$rd.)

[To face page 108.

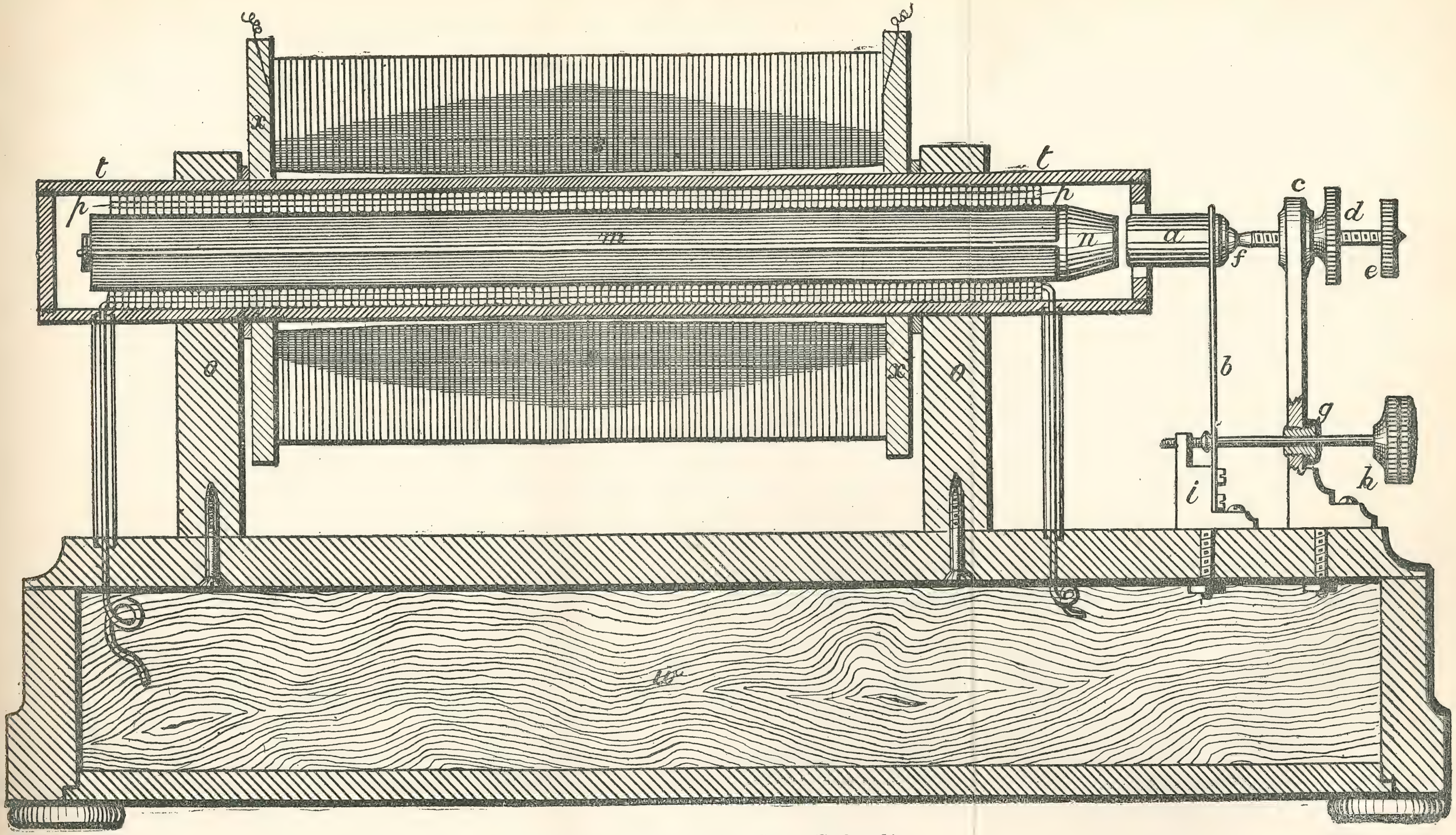


FIG. 98.—A 12-INCH SPARK COIL. (Scale $\frac{1}{3}$rd.)

temperature until no more bubbles rise to the surface of the wax. The bundle should then be allowed to cool slightly, after which it is wrapped from end to end with a layer of paraffined tape, removing the binding wires as the taping proceeds. The weight of the core complete will be about 8 lbs.

Primary Winding.

This consists of three layers of double silk-covered copper wire ·110 inch in diameter. The wire is square in section, whereby less space is wasted, though if this square wire is not procurable No. 12 circular can be employed. The use of square wire is, however, preferable, as a lower resistance of the primary is thus obtained. The winding of the primary is best done by two persons, the one of whom holds the iron core firmly in both hands while the other feeds it on evenly and neatly. A little care is requisite in winding the primary to see that each layer runs on evenly, so that it will, when finished, slide nicely into the ebonite tube. To prevent the end of the wire slipping at the commencement of the winding it should be bound on to the end of the iron core with some stout string, leaving a projecting end of 12 inches for the purpose of afterwards making the connection to the contact-breaker. When finished the coil and primary winding must be immersed in melted paraffin wax and afterwards allowed to drain and cool.

The Insulating Tube.

This is one of the most important parts of the coil; its object being to separate the primary and secondary windings, between which there exists a great tendency to spark. In order, also, to prevent any discharge passing over the end of the tube to the primary it is made longer than the iron so as to completely inclose it. This tube, which is of ebonite, is $21\frac{3}{4}$ inches long by $2\frac{1}{2}$ inches internal diameter and $\frac{1}{4}$ inch thick. It can either be purchased as a tube complete or made up by wrapping warmed sheets of thin ebonite round a metal tube until the required thickness is obtained, fastening the ends of each wrapping by melted shellac. The wound core is slipped inside this tube, which it should just fit nicely; the ends of the primary being brought out at two holes drilled as shown, and the two end pieces of the tube afterwards being cemented in at each end. The two holes through which the ends of the primary pass are tapped to receive the ends of two short lengths of ebonite tube, which serve to conduct the primary ends to the base, the lower ends of the tube being also similarly fitted into the top part of the base. The primary is thus perfectly enclosed in the ebonite tube, the only opening being a $1\frac{1}{2}$-inch hole at the right-hand end through which the hammer of the contact-breaker works. A little consideration will soon show the important part played by the ebonite tube in separating the primary and secondary windings, the tendency of the secondary to spark into the primary being very great.

The Base, Bobbin-Cheeks, and Supports.

The base, which is 28 inches long by 10 wide and 5 deep, is of polished mahogany. It is made hollow, as shown, to contain the condenser, and has affixed to it the two supports, also of mahogany, which are $7\frac{1}{2}$ inches high, by 4 wide and $1\frac{1}{4}$ thick. These supports have a hole just over $2\frac{3}{4}$ inches in diameter bored in the top of each, through which pass the ends of the ebonite tube to support the bobbin, as shown. The bobbin-cheeks, which are of ebonite, are circular in form, 8 inches in diameter, and $\frac{1}{2}$ inch thick. They have a hole bored in their centre of such diameter that they fit tightly on the ebonite tube, as shown in the figure. An ebonite distance ring is placed outside each cheek, which, by butting up against the supports, keep the bobbin-cheeks in place.

The Secondary.

The secondary consists of 12 lbs. No. 36 silk-covered copper wire, wound on in 96 sections or flat rings. It is laid on in a curved fashion, as shown, so as to accord with the direction of the lines of force of the magnetised iron core. The lines of force run somewhat as shown in Fig. 99, from which it will be seen that by winding more towards the centre of the magnet the greatest amount of induction is

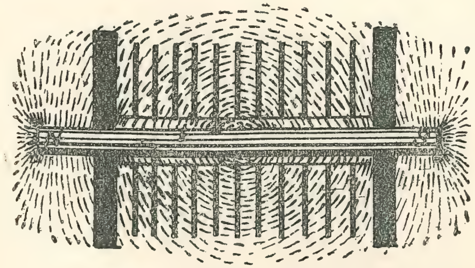


FIG. 99.—MAGNETIC FIELD OF COIL.

obtained. The insulating discs between the different sections are formed of paraffined paper, after the manner first employed by "Inductorium" in 1870. They consist of four layers of some unglazed paper placed in a dish of melted paraffin wax, and allowed to thoroughly saturate, and then removed to drain and cool. While in the wax they should be pressed with the end of a glass rod to squeeze out any air bubbles that may be between them. Out of the 4-ply sheets so formed must be cut 192 circular discs, $7\frac{1}{2}$ inches in diameter, and having a $2\frac{7}{8}$-inch hole in the centre. These being cut out and the wire for the secondary got ready to hand, we can now pass on to

Winding the Sections.

To wind the sections a section-winding apparatus, as shown in Fig. 100, will be required. This consists of a spindle *a*, carrying at the left-hand end a fixed metal disc *b*, $7\frac{1}{2}$ inches in diameter, and having opposite it a similar one *c*, which is movable and can be clamped up to it by the nut *d*. Between the two discs is a movable collar, of which three

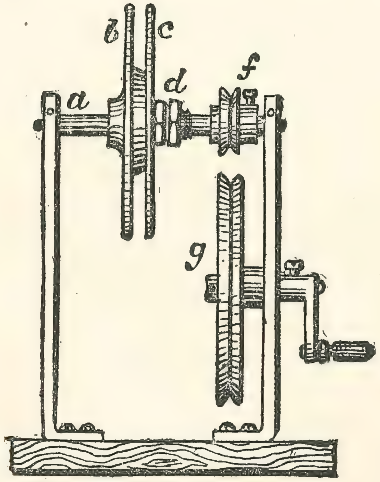


FIG. 100.—SECTION-WINDER.

sizes should be made, each slightly larger than the preceding one. Thus, when one of these collars is placed between the two discs and the nut run up, a thin flat space is formed which, if wound up with wire, will form the wire into a thin flat ring with a hole in the centre, this hole being of sufficient size to allow the ring to slip over the ebonite tube. It is in this manner the sections are formed and slipped on one after the other and joined up together. The

spindle is rotated by means of a band between the pulleys *f* and *g*.

To wind the sections, first the coil of wire which is to feed the section-winder *a*, must be fixed on some such stand as shown at *c* in Fig. 101. From this the wire passes to the tin dish *b*, filled with paraffin wax, kept hot by the spirit lamp seen beneath. The wire passes under a glass rod fixed in the centre of the dish so as to cause the wire to pass through the wax and become thoroughly impregnated with it. From

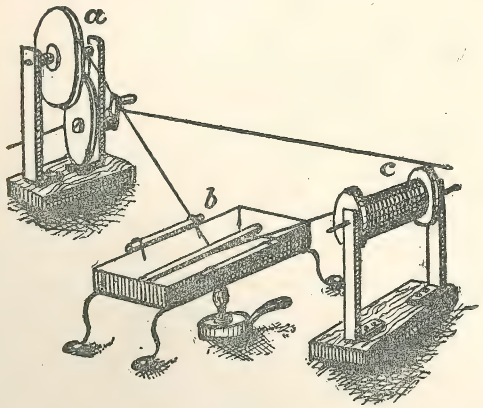


FIG. 101.—WINDING THE SECTIONS.

the rod it passes direct to the section-winder, which is rotated by the handle seen on the right-hand side, the wire being guided on by letting it slide through a small piece of rag at a point midway between the dish and the winder. It will be noticed on looking at Fig. 98 that the sections as they approach the bobbin-cheeks have a wider opening in the centre, the space between the inside of the section and the tube being filled in with paraffin wax. The reason of this is because the tension of the secondary coil is greatest at its ends, and extra precautions are thus necessary at these points to prevent the thickness of the tube being pierced by a spark. It is to form these larger openings in some of the sections that the three different size loose collars for the section winder are required.

Before winding the sections it is well to pencil on the illustration the number of each section, starting, let us say, from the left-hand bobbin-cheek, so that we can mark each section as it is wound with the number of the section to which it corresponds. We then remove the top spindle of section-winder and insert a collar that will give us the required diameter of opening for that particular section we are going to wind, and bolt the whole firmly together by the nut. The movable collar prevents the two discs going up close and the thickness of the collar is such that when screwed up together the distance between the inside edges of the metal discs is just under $\frac{1}{8}$th of an inch. The end of the wire is then passed through a hole in the disc and the space between the discs wound up to the required diameter shown for that disc. The handle can be turned as rapidly as possible, consistent with feeding the wire on without breaking it, as it is unnecessary, even if it were possible, to wind on the wire in even layers; it must be allowed to find its own level. As soon as the section is wound the top spindle must be removed from the winder and the disc arranged so as to be in a horizontal position. The nut is then removed and the top metal disc carefully lifted off. It will now be possible with a knife to detach the wound section from the winder and lay it flat on the table, the whole process being done very carefully and gently. The section will then present the appearance of a flat ring stuck together by reason of the paraffin wax which still adhered to the wire when wound on. The inside end of the section protrudes from the hole in the centre while the outside end passes up over the top. As each section is removed from the winder one of the paraffined-paper discs is placed *each* side

and smoothed on to it by ironing it with a warm flat iron; when one side is done, the section being turned over and similarly ironed on the other side.

In this manner the whole 96 sections are wound, winding those required for the centre portion of the secondary fuller, as in the illustration. It is not necessary to alter the size of each section quite so gradually as shown in the drawing; if changed every sixth section it will be less tedious and just as efficient. When the sections are all completed they must be joined together in pairs, the two inside ends being connected as shown in Fig. 92. This will cause each pair to form a continuous spiral, so that when all the pairs are put on the bobbin the winding will be in the same direction throughout its length. Great care must be exercised in joining up these pairs not to join an inside end to an outside, otherwise the two sections will oppose one another. A glance at Fig. 92 will make this clear. Care must also be taken to join such pairs as will make the secondary, when all the sections are put on, have the form shown in Fig. 98. In joining the sections in pairs, first lay one section on the table and carefully place another one on the top of it. Having cut off all superfluous wire from the two inside ends, carefully scrape and solder them together with a small soldering iron, using resin as a flux. Make as thin and small a joint as possible, and when soldered it must be carefully pushed just between the insulating paraffined paper discs and covered with paraffin. A warm iron should then be taken and the two sections gently smoothed together. After all the sections have been joined in pairs each pair of sections should be separately tested by sliding them one at a time over the ebonite tube containing the primary, and comparing the spark obtained from each pair when a current is sent through the primary and the circuit is made and broken by hand. Any pair of sections that fails to give a spark up to the average obtained from the rest must be inspected, and if not able to be put right a new pair must be wound to replace it. This test should be very carefully applied as it will quickly find out any faulty or improperly connected sections. Presuming we have tested all the sections and obtained good results we can pass on to

Completing the Secondary.

Having arranged the pairs of sections (there will be 48 pairs in all) on the table in the proper order they should go on, support the primary and tube in a vertical position so that it rests on the left-hand ebonite bobbin-cheek, which must be secured in its correct place along the tube by a little shellac varnish. The right-hand bobbin-cheek is not, of course, put on until all the sections have been passed over the tube. The tube being properly supported in a vertical position, the pairs of sections are then slipped on one after the other in their correct order, as shown in Fig. 98. As each pair of sections are put on they must be arranged centrally over the tube and the space between the tube and inside of the section run in with hot paraffin wax until quite full, when it must be allowed to thoroughly set. The wax keeps the sections centrally on the tube and makes an additional thickness of insulation between the primary and secondary, though its main object is to prevent the secondary from sparking from section to section along the surface of the tube by forming a continuous layer of paraffin wax. The wax for this purpose must be very hot, and carefully poured in so as to cause it to penetrate into every little crack. When one pair of sections is cool and set, another must be added, pressed well down against the underneath pair, and served in the same manner, and so on until all are put on, after which the bobbin-cheek is put on and secured in its place.

The outside ends of all the sections must then be joined together, soldered, and the joints pushed down into one of the sections, previously slitting down, however, for an eighth of an inch with a sharp knife, the dividing disc between the two sections to be joined so as to allow the wire to pass. When all the wires are carefully joined up, the coil must be laid on its side and a complete wrapping of thick paraffined paper firmly tied round outside the secondary, the edges of the paper not meeting by a quarter of an inch, but fitting nicely between the bobbin-cheeks. Melted paraffin wax must then be poured in along the slot till all the vacant space above the wire in each section is filled, and a solid jacket of paraffin wax thus cast over the secondary. This must first be allowed to thoroughly cool and harden, after which a wrapping or two of paraffin-paper may be put round as a finishing layer. The surface of this may be finished off either with a wrapping of thin sheet ebonite or a layer of black thread served afterwards with a coat of varnish.

The Contact-Breaker.

This is of the improved form devised by Mr. Apps, and used in his well-known coils. It consists of the upright spring *b*, carrying the soft iron hammer-head *a*, which works through the opening in the end of the tube as shown. This spring is screwed to a massive brass foot *i*, which in turn is bolted to the top portion of the wood base by the nut and bolt shown. Behind the spring is the upright standard *c*, carrying the heavy contact-screw *e*, and back-nut *d*. The front of the contact-screw has a substantial platinum point which makes contact with the platinum point on the back of the hammer-head. Through a bone bush *g*, in the bottom of the standard, passes a brass rod fitted at one end with the milled ebonite disc *h*, and at the other working in a threaded hole in the foot *i*. It will thus be seen that according to the direction in which the disc *h* is turned, so the spring and hammer-head are forced towards or away from the contact-screw. The action of the contact-breaker is as follows:—The greater the pressure there exists between the hammer-head and the contact-screw the more completely must the iron core of the coil be magnetised before it has sufficient power to attract it and thus break the circuit. Moreover, as soon as it is thoroughly magnetised the circuit is very suddenly broken. By varying the pressure of the spring by means of the disc *h*, it will be seen that the interruptions can be accomplished either when the core is slightly magnetised or very strongly magnetised only. To get the best results from a spark coil it is necessary that the core be fully magnetised before the circuit is broken, and when broken it should be done instantly. This form of contact-breaker allows, it will be seen, a ready adjustment to this end. It is not an easy matter with an automatic contact-breaker to get the best results from a coil of this size; in fact if the object is to get the longest possible sparks from the coil, it will be found advantageous to rig up a temporary hand-break for the occasion and cut out the automatic break, which can easily be done by screwing up the contact-screw.

The Condenser.

The condenser, which is contained within the base (though not shown in the figure), consists of 60 sheets of tin foil, 12 inches by 8, interleaved with sheets of paraffined paper as previously described; the whole is afterwards well pressed together and clamped between two thin boards. The connections to the two parts of the contact-breaker from the condenser consist of sheet foil rolled up into a strip of six thicknesses, soldered at one end to the foil and clamped at the other underneath the nuts of the contact-breaker. For those who like to ascertain for themselves experimentally the best size condenser for the coil, this can easily be done

by gradually adding more sheets to the condenser while the coil is working, watching the spark at the terminals of the secondary until a point is reached where the addition of more sheets is not accompanied by any increase in the length of the spark. It is preferable in most instances when making a coil, to find out *experimentally*, as described above, the best size of condenser to employ, taking care that the normal battery-power that will be employed is used.

Finishing off the Coil.

All being completed the final mounting up may now be done, and finishing touches given the coil. The bobbin is placed in its supports and the supports screwed to the top part of the base by four substantial screws. The contact-breaker must then be correctly mounted in its place, the condenser inserted inside the base and connected up, after which the bottom part of the base is screwed down. The primary terminals must be fixed at the most convenient place, which will be found to be on the right-hand side of the contact-breaker, looking at the coil from the contact-breaker end. A commutator or current-reverser will be found a great convenience, and if it is desired to add one this can be placed close to the primary terminals. The bobbin is not placed quite centrally of the base, but slightly to one side so as to make room for the two ebonite discharging pillars, on the top of which are mounted the secondary terminals after the manner shown in Fig. 96. The wires from the secondary to the terminals on the pillars hang, it will be seen, in mid-air, but are enclosed in a piece of indiarubber tube, the inside of which is run in with paraffin wax, care being taken to see that a good union is made with the wax on the coil.

With two or three large cells (Bunsen, Grove, chromic acid, Edison-Lalande or accumulators) giving about 12 ampères in the primary circuit, a spark 12 inches in length is easily to be obtained from this coil. Should good results not be obtained with the automatic contact-breaker after repeatedly trying to adjust it, a hand make-and-break should be temporarily substituted to ascertain whether the fault is with the contact-breaker or not. If sparks of the full length are then obtained it is evident the contact-breaker is at fault, which must be carefully inspected and altered.

App's noted Spark Coils.

The palm for constructing large spark coils must undoubtedly be awarded to Mr. Alfred Apps, whose magnificent productions cannot fail to elicit the admiration of all who have had the pleasure of seeing these monsters at work. His most notable production is the famous Spottiswoode coil, of which an illustration and description are given on p. 123.

Another coil, also equally well known, and perhaps one which many of my readers may have had an opportunity of seeing, if not in the vigour of its youth no doubt in its old age, when its sparking capabilities had somewhat fallen off owing to a slight break-down in its insulation, is the Polytechnic one. This coil, although it gave a magnificent spark of 29 inches, sinks into insignificance beside the Spottiswoode, which produced sparks 42 inches long.

Mr. Apps' method is to wind his secondary sectionally, dividing it into a large number of small sections and frequently to separate these into four large sections, as in the case of the Spottiswoode coil. The primary is placed inside a massive ebonite tube (½ inch thick in the Polytechnic coil) and the insulating discs between are also of ebonite. The core and primary project beyond the ends of the secondary while the tube projects beyond the core so as to completely enclose it after the manner described for the coil on p. 109.

Much of Mr. Apps' success in coil constructing, however, is no doubt due to the skill he has acquired and large experience he has gained during the years he has applied himself so assiduously to the production of these monster coils.

The Polytechnic Coil.

The core of this wonderful coil was composed of No. 16 iron wire, its total length being 5 feet, its diameter 4 inches and weight 123 lbs. The primary consisted of 600 turns (3770 yards) of ·095 copper wire and had a resistance of 2·2 ohms. This primary was enclosed in an ebonite tube 8 feet long and ½ inch thick, centrally of which was placed the secondary, consisting of 150 miles (606 lbs.) of ·014 silk-covered copper wire, the whole secondary occupying a space along the tube of 54 inches. When completed the secondary bobbin was 2 feet in diameter, and 4 feet 10 inches in length, over all dimensions. With a battery of 40 large Bunsen cells the coil gave secondary sparks 29 inches long and would pierce blocks of glass 5 inches in thickness.

Referring to the break-down of this coil Mr. Paul Ward, who, under Mr. Apps' personal directions, had the construction of it entrusted to him, sent to the *English Mechanic* in 1886, in answer to the enquiries of a correspondent, the following interesting particulars:—

"The Polytechnic coil broke down twice, but from no fault in the principle of construction. The first of these failures (and this is, I think, the only time that the causes have been made public, and I am glad to afford this information in justice to its designer) was due to some experiments made by Professor Pepper, in using a too small part of the condenser, which was made in ten sections. The extra spark, or induced current in the primary itself could not find sufficient capacity in the small condenser, at that moment being used, and it found circuit by breaking from one layer of the primary to another. This soon got worse the more the coil was used, and eventually there was a complete short circuit in the primary, caused by melted spicula of copper bridging across the two contiguous layers. This was repaired, and the coil worked as well as ever. The second break-down was of a more serious nature, and consisted in the piercing of the primary tube. It must be remembered that this huge masterpiece weighed nearly a ton, and it required special means and intelligent administration in moving such a monster. But owing, I am sorry to say, to the parsimony of the directors of the Polytechnic, they did not avail themselves of these two most necessary elements to success. They elected to move it themselves, and, owing to an enormous undue strain being put on the primary tube in so doing, it was either cracked incipiently or so weakened that when they separated the terminals a certain distance, through went a spark. This time, however, the damage was repaired by Mr. Apps, which, I am sure, every one who knows anything of the almost insurmountable difficulties of withdrawing the old tube and putting in a new one without damaging the ponderous and delicate secondary, will admit was a triumph of mechanical skill. The last time I saw the coil was in the Loan Collection at South Kensington. With regard to the proportion of length of spark to the length of body, this is no matter for surprise, considering that the thickness of the secondary was not of that diameter to get the maximum length of spark. All who witnessed the thickness of the secondary flame, for flame it really was, could not fail to be impressed by the enormous quantity; and in support of this I may add that three sparks from it were sufficient to charge twelve 9-gallon Leyden jars to saturation."

The Spottiswoode Coil.

In the *Philosophical Magazine* of January 1887 there appeared this well-known description of Apps' monster coil by the owner himself, the late Mr. Spottiswoode, of Sevenoaks, which cannot be better reproduced than in his own words.

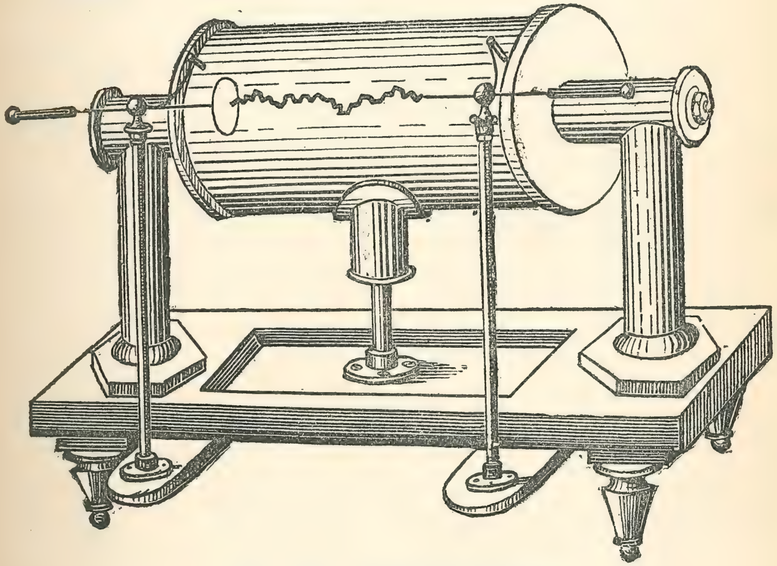


Fig. 102.—THE SPOTTISWOODE COIL.

"The general appearance of the instrument is represented in Fig. 102, from which it is seen that the coil is supported by two massive pillars of wood, sheathed with gutta-percha and filled in towards their upper extremities with paraffin wax. Besides these two main supports, a third, capable of being raised or lowered by means of a screw, is placed in the centre, in order to prevent any bending of the great superincumbent mass. The whole stands on a mahogany frame resting on casters.

"The coil is furnished with two primaries, either of which may be used at pleasure. Either may be replaced by the other by two men in the course of a few minutes. The one to be used for long sparks, and indeed for most experiments, has a core consisting of a bundle of iron wires, each ·032 inches thick, and forming together a solid cylinder 44 inches in length and 3·5625 inches in diameter, has a conductivity of 93 per cent., and offers a total resistance of 2·3 ohms. It contains 1344 turns, wound singly in six layers, has a total length of 42 inches, with an internal diameter of 3·75 inches, and an external of 4·75 inches. The total weight of this wire is 55 lbs.

"The other primary, which is intended to be used with batteries of greater surface, e.g. for the production of short thick sparks, or for spectroscopic purposes, has a core of iron wires ·032 inches thick, forming a solid cylinder 44 inches long and 3·8125 inches in diameter. The weight of this core is 92 lbs. The copper wire is similar to that in the primary first described, but it consists of 504 yards wound in double strand, forming three pairs of layers whose resistances are ·181, ·211 ohm respectively. Its length is 42 inches, its external diameter 5·5 inches, and its internal 4 inches. Its weight is 84 lbs. By a somewhat novel arrangement these three layers may be used either in series as a wire of ·192-inch thickness, or coupled together in threes as one of ·576-inch thickness. It should, however, be added that, owing to the enormous strength of current which this is capable of carrying, and to the highly insulated secondary coil being possibly overcharged so as to fuse the wire, this larger primary is best adapted for use with secondary condensers of large surface, for spectrum-analysis, and for experiments with vacuum tubes in which it is desirable to produce a great volume of light of high intensity, as well as of long

duration at a single discharge. The alternate discharges and flaming sparks can also be best produced by this primary. It has been used for high-tension sparks to 34 inches in air, the battery being 10 cells of Grove's, with platinum plates $6\frac{1}{4}$ inches by 3 inches. Great facilities for the use of different sets of batteries are afforded by the division of this primary into three separate circuits, to be used together or separately, and by a suitable arrangement of automatic contact-breakers the primary currents may be made to follow in a certain order as to time, duration and strength, with effects which, when observed in the revolving mirror, will doubtless lead to important results in the study of striæ in vacuum tubes.

"The secondary consists of no less than 280 miles of wire, forming a cylinder 37·5 inches in length, 20 inches in external and 9·5 inches in internal diameter. Its conductivity is 94 per cent., and its total resistance is equal to 110,200 ohms. The whole is wound in four sections, the diameter of the wire used for the two central sections being ·0095 inch, and those of the two external being ·0015 inch and ·0110 inch respectively. The object of the increased thickness towards the extremities of the coil was to provide for the accumulated charge which that portion of the wire has to carry.

"Each of these sections was wound in flat discs, and the average number of layers in each disc is about 200, varying, however, with the different sizes of wire, &c. The total number of turns in the secondary is 341,850. The great length of wire necessary can be easily understood from the fact that near the exterior diameter of the coil a single turn exceeds 5 feet in length. The spark, it is believed, is due to the number of turns of wire rather than to its length, suitable insulation being preserved throughout the entire length. In order to ensure success the layers were carefully tested separately and then in sets, and the results noted for comparison. In this way it was hoped that, step by step, safe progress would be made. As an extreme test as many as 70 cells of Grove's have been used with no damage whatever to the insulation.

"The condenser required for this coil proved to be much smaller than might at first have been expected. After a variety of experiments it appeared that the most suitable size was that usually employed by the same maker with a 10-inch spark coil, viz. 126 sheets of tin foil, 18 inches by 8·25 inches in surface, separated by two thicknesses measuring ·011 inch. The whole contains 252 sheets of paper, 19 inches by 9 inches in surface.

"Using the smaller primary this coil gave, with five quart cells of Grove's, a spark of 28 inches, with 10 similar cells, one of 35 inches, and with 30 such cells one of 37·5 inches, and, subsequently, one of 42 inches. As these sparks were obtained without difficulty, it appears not improbable that if the insulation of the ends of the secondary were carried further than at present a still longer spark might be obtained. But special adaptations would be required for such an experiment, the spark of 42 inches already so much exceeding the length of the secondary coil.

"When the discharging points are placed about an inch apart, a flowing discharge is obtained both at making and at breaking the primary circuit. The sound which accompanies this discharge implies that it is intermittent, the time and current spaces of which have not as yet been determined.

"With a 28-inch spark, produced by five quart cells, a block of flint glass 3 inches in thickness was in some instances pierced, in others both pierced and fractured, the fractured pieces being invariably flint glass. If we may estimate from this result, the 42-inch spark would be capable of piercing a block 6 inches in thickness.

"When used for vacuum tubes this coil gives illumination

of extreme brilliancy and very long duration; with 20 to 30 cells and a slow-working mercury break, giving, say, 80 sparks per minute, the striæ last long enough for their forward and backward motion to be perceived directly by the unassisted eye. The appearance of the striæ when observed in a revolving mirror was unprecedently vivid, and this even when only two or three cells were employed.

"Further experiments have shown that with such large coils only the newly-discovered effects of very high temperature combustion or volatilisation can be produced. On exciting the primary of the coil with a suitable dynamo-electric machine or battery, and using a large Leyden jar in the secondary circuit (according to Sir William Grove's experiment), the electrical discharge passing between electrodes placed before the slit of the spectroscope, lines and bands may be observed to advance and recede according to the variations made in the magnitude of the exciting discharges. As the atmospheric pressure may be assumed to remain constant, these effects are probably due to differences of temperature arising from the action of a greater or smaller extent of electrical effects on the electrodes in a given time."

In the *English Mechanic* of 1886, Mr. Paul Ward gives a description of some further effects produced by this coil as follows:—

"In conducting some experiments for the late Mr. Spottiswoode on 'The Electric Discharge in Vacuo,' it occurred simultaneously to that gentleman and myself that it would be possible to work an induction coil without a contact-breaker and without a condenser by means of a powerful alternating current sent through the primary of such an instrument. This we found to be possible, and the effects obtained were truly prodigious.

"The equality of discharge between the poles of the secondary was remarkable, as evidenced by placing a vacuum tube, giving well-developed striæ, in the secondary circuit.

The appearance was one of great beauty, the tube in question being filled with a double set of pearl-like striæ of 2 inches diameter, devoid of all motion, for they were as steady as a rock. This was caused by the rapidly alternating discharges from the secondary, and was very fine as a spectacle. . . . It may be of some interest to your readers that I quote from Mr. Spottiswoode's description of the appearance produced by the excitation of an induction coil by an alternate current, sent through the primary of such an instrument.

"'The spark from this machine (a coil excited by a De Meritens machine) presented an unusually thick yellow flame, and it was accompanied by a hissing noise, different from that commonly heard with a coil excited by a battery. As the machine gives alternate currents, the secondary discharge presents sparks of equal length in both directions, and the general appearance to the eye is symmetrical in respect of both terminals. The spark was observed in a revolving mirror, first in a vertical, and secondly in a horizontal direction; the discharge, although apparently continuous, was immediately seen to be intermittent, with a period in unison with that of the exciting machine. Tongues of flame, leading alternately from one terminal and from the other, crossed the field of view. . . . When the length was increased to 2 inches, flashes or bands of continuous light were seen to traverse the field of view in diagonals of low slope (i. e. nearly horizontal), showing that there were masses of heated material passing from time to time at a moderate velocity between the terminals.

"'From the known period of the machine, and the number of discharges crossed by these flashes in their passage from terminal to terminal, it was calculated that the time of passage was about ·03 of a second. Occasionally there was a still brighter flash of meteor, which similarly traversed the field, but with a velocity apparently of about double that of the others.'

"These rapidly alternating discharges," Mr. Ward continues, "though very fine as a spectacle, were unsuited for the investigation of the laws which Mr. Spottiswoode established relative to the nature and behaviour of a discharge in a rarefied atmosphere. The two sets bothered us. We wanted only one set, and I was asked to devise an instrument for stopping, or shunting off, one of these alternate sets of currents."

An ingenious piece of apparatus Mr. Ward devised for this purpose, to which he gave the name of "Electric Valve," and the writer's only regret is that space will not permit its reproduction here. Those of my readers, however, who wish for a full description and illustrations of it are referred to the *English Mechanic* of March 26, 1886.

CHAPTER VI.

EXPERIMENTS WITH SPARK COILS.

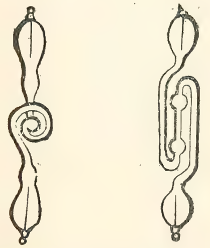
Perhaps no other amusement for a winter's evening is so much enjoyed by the amateur coil-maker as that of experimenting with his newly-constructed coil. A large number of experiments are capable of being performed with a good spark coil, while the performing of these experiments and endeavouring to find out fresh ones is a pastime of great interest. In carrying out these experiments the coil should not be less than $\frac{3}{4}$-inch spark, while if it is $1\frac{1}{2}$, 2 or 3 inches the better will be the performance of the experiments and the greater the interest attached to them. Of course these large spark coils must not be handled carelessly, and great caution must be exercised by the operator not to get included in the path of the discharge, otherwise unpleasant and perhaps fatal results may occur. The primary circuit should *always* be interrupted when obliged to adjust in the neighbourhood of the secondary terminals, and all adjustments that must be made while the coil is in operation should be done by means of a glass rod held in the hand. If the coil has not a discharger already fixed on the base it will be advisable to make one, as shown in Fig. 29, p. 41, as the experiments can by this means be more conveniently performed.

On starting the contact-breaker and adjusting the one point of the discharger towards the other, a rapid flow of sparks will take place between the points, the spark being

short, thick and reddish when the points are close together, and thin, bluish-white and less frequent when far apart. The red spark, when the two points are close together, is the spark most suitable for igniting such substances as it is possible to ignite with a coil.

Vacuum Tubes.

Experiments with vacuum tubes are those most frequently carried out with spark coils and are certainly the most beautiful. Vacuum tubes, first devised by Giessler, of Bonn, are thin glass tubes variously shaped and provided



Figs. 103, 104.—VACUUM TUBES.

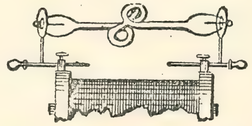


Fig. 105.—SIMPLE METHOD OF HOLDING TUBES.

with a metal connection at each end, which connections project a short way into the tube. The tubes are then partially exhausted or filled with different gases and hermetically sealed. On connecting up these tubes to the ends of the secondary coil and starting the contact-breaker a beautiful discharge takes place, completely filling the tube with a luminous glow. The tubes are not completely exhausted, as the spark will not pass in a vacuum, any more than it would if the tube was filled with air; it is necessary to have a rarefied medium of some description.

Figs. 103 and 104 show two of the more common forms of vacuum tubes which, it will readily be understood, must be carefully handled to avoid breakage. A very convenient method in which they can be connected to the coil is shown in Fig. 105. The colour of the luminous effects obtained is varied both by filling the tubes with different gases and also by using glass with metallic oxides in its composition. Thus nitrogen gas inside the

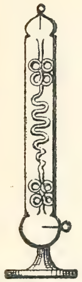


Fig. 106.

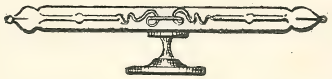


Fig. 107.

tube will give a rose colour, while if the glass has oxide of uranium in it a bright green colour will be the result. Compound vacuum tubes are tubes which, owing to the intricacy of their design, are extremely fragile and are therefore enclosed in a second outer tube of glass, as in Figs. 106 and 107, which

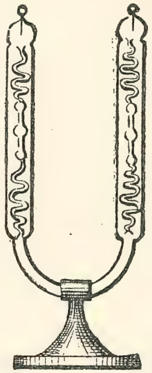


Fig. 108.—Compound vacuum tube.

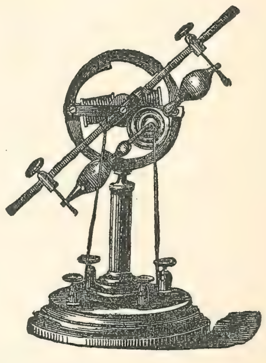


Fig. 109.—Vacuum tube rotator.

show the vertical and horizontal form. The horizontal form shown in Fig. 107, when it has letters inside, is known as a

motto tube. Tubes are also made of the shape shown in Fig. 108, when they are known as U-shape or double-branch tubes. A very fine effect can be obtained by placing in a vacuum rotator any of the simple form of tubes and lighting them up while they are turning round, thus giving the appearance of a wheel of flame. These vacuum tube rotators are made to be operated either by hand or a small electro-motor, one of this latter form being shown in Fig. 109.

Altering Length and Character of the Spark.

The length and character of the spark obtained between the ends of the secondary can be influenced in a great number of ways.

Hold a lighted match or candle just below the spark and it will be found that the length of the spark can be enormously increased by widening the gap, while, moreover, the spark will assume a deep violet colour. The increased length of spark thus obtained is due to the heated air being a better conductor.

Again, place the candle on one side of the sparks and it will be found that sparks will be diverted slightly out of their course in order to pass through the flame.

Place the candle right between the points of the discharger so that the sparks must pass through the flame and the sparks will become of vivid brightness. Raise the candle slightly so that the sparks pass round the wick and they will become of a blue character. Blacken the points of the discharger so that they are covered with lamp-black, and on bringing the points close together the black points will be rendered incandescent.

The spark is easily pushed out of its course, as it were, by any non-conductor, as may be seen as follows:—Separate the points of the discharger to a medium distance, and then, while the sparks are passing slowly, insert the edge of a sheet of glass or piece of bone, wood, &c., and the sparks will be seen to bend round the edge of the glass. If a piece of paper is inserted the spark will be seen to pierce the paper, and on holding the punctured part up to a strong light there will be seen to be two holes side by side as if there had been a double spark.

Action of Sparks on Metal Filings, &c.

Grind down to a fine powder some mixed steel and copper filings and place them on a piece of wood or ebonite on which the two points of the discharger are resting. The sparks will then be seen to pass in all directions, fusing particles of the metal here and there and acquiring a red colour. Clear away the filings and substitute some fine non-conducting powder such as crystallised gallic acid, and as soon as the sparks commence the particles of powder will be seen to be in motion. The particles will seem as though blown away from one point of the discharger until a division is made across the mass of powder to the other point.

Ignition Experiments.

Hydrogen gas can easily be ignited by the spark, as can easily be seen by arranging the two points of the discharger so that the sparks pass across the top of a gas-burner.

Gun-cotton, gunpowder, lycopodium and phosphorus can also similarly be ignited by the sparks, to do which they must be placed on a glass plate or marble slab and the ends of the discharger brought rather close together. The gunpowder must be finely ground for this experiment and the ycopodium dusted on some cotton wool.

A fuse, such as is used for firing charges of gunpowder or gun-cotton, can easily be made as follows:—Make a small paper tube just large enough to slip over the ends of two gutta-percha-covered wires, twisting the one round the other,

and the ends of the wire being bared of their insulation for $\frac{1}{16}$th of an inch. Bend these bared ends so that they come within $\frac{1}{8}$th of an inch of one another, and then fill in the tube with fine gunpowder, taking care that it falls in well between the points of the wires. The end of the fuse must then be closed with a little sealing-wax, taking the precaution, however, of inserting a wad of paper first. If the ends of the secondary are connected to the two free ends of the wire the fuse will go off with a loud report and fire any gunpowder or gun-cotton in which it is placed. Gun-cotton can of course be used in the fuse instead of gunpowder, or a mixture of chlorate of potash, phosphide of copper and sulphide of copper, as in Abel's fuse.

Experiments with Water and other Fluids.

Sparks can be made to pass through water by taking two gutta-percha-covered wires, as explained for the fuse, and twisting them together so that the ends are $\frac{1}{8}$ inch apart. Plunge these ends into a glass of water, the other ends being connected on to the discharger, and the spark will be seen still to pass between the ends of the wire.

If one of the wires from the discharger be placed in a glass of water and the other brought close to the surface, sparks will be seen to pass between the point of the discharger and the water. If a drop of water is placed on a slab of marble or sheet of glass and the points of the discharger brought close on each side of it the sparks will be seen to pass over or round the edge of the water. Substitute a drop of oil for the water and the oil will quickly appear to work into a state of effervescence. If the drop of water be placed on an ebonite plate and smeared over its surface, when the two points of the discharger are made to touch the wetted surface the spark will assume a twisted shape and be capable of being made very much longer.

Detonating Plane and Leyden Jars.

Leyden jars can readily be charged by a spark coil, to do which one point of the discharger must be placed in contact with the outer covering of the jar while the other is directed towards the brass nob and sparks allowed to pass. In place of a Leyden jar a detonating plane can be employed, which consists of a sheet of *good* glass, 12 to 18 inches square, on both sides of which are stuck, by means of some shellac varnish, a sheet of tin foil, leaving a margin of $\frac{1}{4}$ inch of glass all round. When one point of the discharger is placed against one sheet of tin foil and the other against the opposite one, a bright spark will pass from one sheet to the other, accompanied by a loud report as soon as the sheets become sufficiently charged.

CHAPTER VII.

BATTERIES FOR COIL WORKING.

For working induction coils the most suitable batteries are the Bunsen, bichromate, Edison-Lalande, Leclanché and dry batteries. The most important points in an ideal battery for coil working are constancy, small space, light weight and cleanliness, but since no battery fulfils all these conditions we must select from those above the form best suited to the particular work we have in hand.

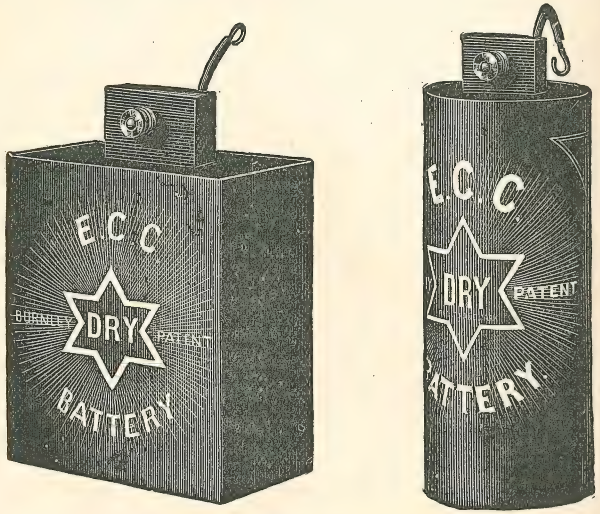
Batteries for Medical Coils and Galvanisation.

The batteries best suited for this purpose are dry batteries, Leclanché, bichromate and the Edison-Lalande.

Dry Batteries.

These are chiefly employed for portable sets where, of course, a battery that is free from the slopping and spilling of acids is a great desideratum.

Of course it is now generally understood that all so-called dry batteries are in reality moist, and dry only in comparison with batteries in which liquids are freely used. The exciting composition is in the form of a paste or jelly, the viscidity of which varies with the temperature, and once the composition of this jelly became generally known, innumerable forms of dry batteries sprang into existence. The various makes are almost identical in their construction, so one make only is shown, viz. Burnley's cell, as made by the General Electric Company, two forms of which are figured in Figs. 110 and 111. The containing case is of zinc, and forms the one element, while the other consists of a carbon plate, the intervening space between the two elements being filled with the exciting paste. The top of the cell is run in with melted pitch, and



FIGS. 110, 111.—DRY BATTERIES.

the outside of the zinc case pasted round with paper. A wire is soldered on to the zinc case as a connection from the one pole, the carbon pole being bored and fitted with a terminal, as shown. Since the outer case forms one of the poles, it is necessary to see, when setting up a battery, that the different cells do not touch one another. For this reason it is usual to divide up the battery box by means of wood partitions, so that a division is provided for each cell, though

some makers supply with their batteries a special cardboard containing box, into which the cell is slipped, and thus kept, not only from contact with its neighbours, but also with the ground. Fig. 110 shows the square form of this cell, which is made only in one size, viz., 6 by $4\frac{1}{2}$ by $2\frac{1}{2}$ inches, and owing to its shape occupies a minimum of space consistent with its large power. Its internal resistance is ·30 of an ohm, the E. M. F. being, of course, 1·55 for all sizes. Fig. 111 shows the round form, of which four sizes are made, No. 1 being 8 inches in height, $3\frac{1}{4}$ in diameter, and has a resistance of ·35 of an ohm, while No. 2 is 7 inches high, $2\frac{1}{2}$ in diameter, with an internal resistance of ·70 of an ohm; No. 3 is $5\frac{3}{4}$ inches high, 2 inches in diameter, and has a resistance of ·85 ohms; and No. 4 is $4\frac{1}{4}$ inches high by $1\frac{1}{2}$ in diameter, and has a resistance of about 1 ohm.

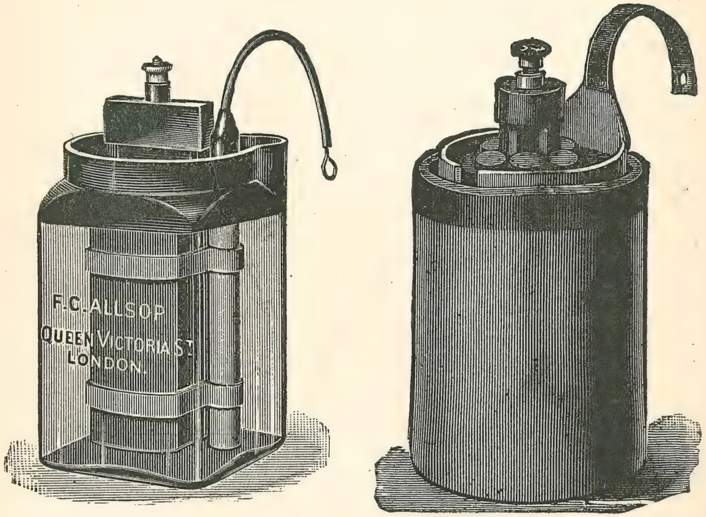
Dry batteries, when exhausted, may be recuperated by passing a current of 1 to 2 ampères for an hour or so through the cell the reverse way, though the best way is to return them to the manufacturers who will usually exchange them for new ones at a slight charge.

Leclanché Batteries.

Leclanché batteries are now too well known to need any description, save to point out which forms are most suitable for coil working. The No. 2 size is the one most frequently employed, and the agglomerate block (see Fig. 112) having a lower resistance than the porous pot form, is capable of giving the most powerful results. Whether porous pot or agglomerate block form be used, however, they should, if required for a portable set, be sealed across the top to prevent spilling the liquid.

The proper charge for the No. 2 size agglomerate cell is 3 oz. of sal-ammoniac, and water must be poured in up to the blackened part of the glass jar. Some persons prefer to use a stronger solution, but this is not recommended, as, with a saturated solution, trouble from a creeping of the salts arises.

For working large coils where the battery is only required for short periods with long intervals, the six-block agglomerate-cell, as shown in Fig. 113, will be found very convenient. It consists of a zinc cylinder, inside which is a grooved carbon rod, each groove being fitted with manganese blocks, and the



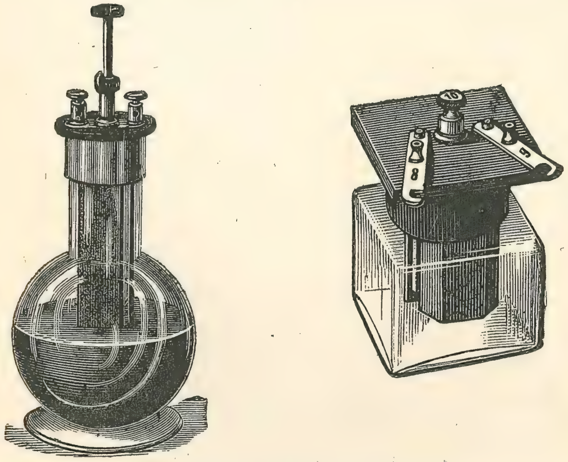
FIGS. 112, 113.—LECLANCHÉ BATTERIES.

blocks kept in contact with the rod by a wrapping of sack-cloth and two elastic bands. The cell has a very low resistance (·03 of an ohm) and once set up will last for years with occasional use.

For a more detailed description of the Leclanché battery the reader is referred to 'Practical Electric-Bell Fitting,' where a full description will be found.

Bichromate Batteries.

The bottle form of bichromate battery (Fig. 114) has long been a favourite battery for working, not only small medical and shock coils, but also for spark coils of somewhat large dimensions. The zinc rod being capable of being quickly and easily removed from the solution, which has thus not to be poured out, makes the cell a very convenient one, while, taking into account its high E. M. F. and low resistance com-



FIGS. 114, 115.—BICHROMATE BATTERIES.

pared to its small size, it is easy to see why, where somewhat strong currents are required, this cell is always selected. These cells are made in three sizes, the half-pint, pint and quart.

When the battery is required to occupy a small space, such as when fitted in a portable set, the form of bichromate cell generally used is shown in Fig. 115. It consists of a small, square-shaped, glass containing jar, into the top of which are fitted the two carbon and one zinc plates, after the manner employed in the bottle form, the zinc being similarly removable by lifting up the knob (10) of the brass rod. The brass pieces 8 and 9 are the connecting pieces for the coil, and swing round so that the hooked portions fit on to the terminals. The square ebonite top of the cell is usually let in flush with the woodwork of the case, so that only the top is thus visible.

Bichromate batteries are now usually charged with a chromic acid solution, the crystals for making which can be purchased in tins and bottles, so that all that is necessary is to dissolve the crystals in water and the solution is ready. For a bichromate of potash solution the proportions are as follows :—

Bichromate of potash	6 oz.
Water (hot)	2 pts.
Sulphuric acid	6 oz.

The E. M. F. of the bichromate battery is 1·9 volt.

The Edison-Lalande Battery.

It is only quite recently that the Edison-Lalande battery has attracted much attention in this country. It is an improvement by that great inventor, Thomas Alva Edison, on the Lalande-Chaperon battery, and has so many good points that, when better known and its action understood, it must come largely into use. Its most important points are :—

1. Great constancy.
2. Entire freedom from local action when on open circuit.
3. Low internal resistance.

The containing jar of the Edison-Lalande battery (see Fig. 116) is of glass, or else white glazed porcelain, and the elements employed are zinc as the positive, and black oxide of copper (CuO) as the negative. The exciting liquid is simply a solution of caustic potash. The oxide of copper is

obtained by the process of roasting copper-scale, the oxide being afterwards ground into a fine powder and compressed into solid blocks. From these blocks plates of a suitable size for the different cells are cut, which are then reduced on the surface to form a good conductor. These

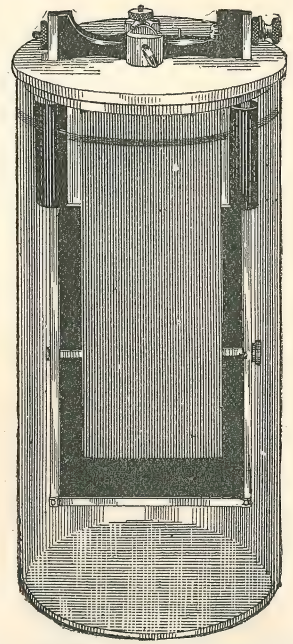


FIG. 116.—EDISON-LALANDE BATTERY.

plates are suspended from the cover of the containing jar by means of a light framework of copper, one end of this framework carrying the terminal for the positive pole of the battery. On each side of the copper element in the larger type of cells (but on one side only in the smaller types) is suspended a rolled zinc plate. The terminal, which is attached to the zinc plate, has an ebonite or vulcanised fibre extension yoke, both ends of which fit closely into the grooved sides of that portion of the copper frame above the cover, to which they are firmly bolted. This prevents any movement in the relative position of the elements, and does away with the necessity of using separators to prevent any short circuits occurring between the elements in the solution. The zincs are amalgamated, and, as in most batteries, the zinc is attacked more vigorously near the top than at the lower part of the plate. The zincs for this cell are made slightly tapering, the thick part being uppermost.

The exciting liquid employed in the battery consists, in all types, of 25 per cent. solution of caustic potash in water; or, in other words, of a solution of one pound of caustic potash in three pounds of water. When the circuit is closed and the cell is put into action, the water is decomposed and the oxygen forms with the zinc oxide of zinc, which in turn combines with the potash to form an exceedingly soluble double salt of zinc and potash that dissolves as rapidly as it is formed, while the hydrogen, liberated by the decomposition of the water, reduces the copper oxide to metallic copper. This reduced copper is of great purity, and can, moreover, if desired, be converted again into copper oxide. The potash is manufactured in sticks, varying in size according to the type of cell, and when the solution is exhausted a renewal is effected by simply placing a stick in the cell and pouring in the requisite quantity of water. A layer of heavy paraffin oil, $\frac{3}{8}$ inch deep, is poured on top of the solution to exclude the air and prevent creeping. As for inspection and supervision, it suffices to say that, when once set up, the battery may be left, like the Leclanché, for months together without inspection and without trouble arising from creeping of the solution or noxious fumes.

There are three sizes of the Edison-Lalande battery

commonly employed, size No. 1 having a capacity of 600 ampère hours, the dimensions of the containing-jar being $11\frac{1}{2} \times 5\frac{1}{2}$ inches. Size No. 2 has a capacity of 300 ampère hours, and the jar is $5\frac{1}{2} \times 3\frac{3}{4}$ inches; while size No. 3 is of 150 ampère hours, and has a jar $5 \times 2\frac{1}{2}$ inches.

For Galvanisation or constant current application, the batteries employed are generally either dry batteries, chloride of silver, or the Edison-Lalande.

Batteries for Spark Coils.

For spark coils, of course, a very much stronger current is required to satisfactorily work them than what is necessary for a medical coil: first, because the primary consists of few turns of very thick wire and has a low internal resistance; and, secondly, because we wish to get from the secondary very much more powerful results. The batteries chiefly employed to work large spark coils are the Bunsen, Grove, bichromate and Edison-Lalande, because all these forms have a very low internal resistance, and, with the exception of the last named, a high electromotive force.

The Bunsen Battery.

This battery (see Fig. 117) consists of an outer glazed porcelain or stoneware jar, inside which is a cylinder of zinc forming the negative element, while the positive element consists of a carbon rod or bar contained in a porous pot placed inside the zinc cylinder. The exciting solutions are: old method, concentrated nitric acid for the carbon, and sulphuric acid, 1 part to 10 in water, for the zinc; new method, saturated solution of nitrate of soda and nitric acid (half in volume), a little bichromate of soda being sometimes added. The zinc is amalgamated, and special brass terminal clamps are provided for each element, as shown in the figure. The electromotive force of the Bunsen cell varies from 1·0 to 1·9 volts according to the strength of the solutions.

The Grove battery differs only from the Bunsen in the negative element, for which a platinised silver plate is substituted for the carbon rod. It is more expensive both in first cost and maintenance, and as its only advantage is a slightly lower internal resistance, of the two the Bunsen cell

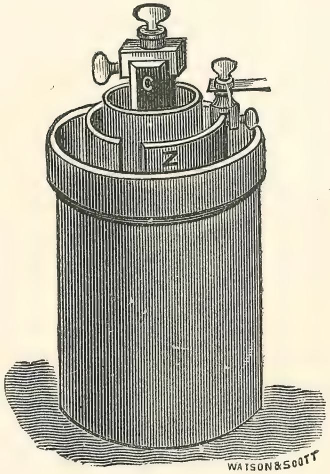


FIG. 117.—BUNSEN BATTERY.

is generally used in preference. Both batteries give off noxious fumes from the nitric solution in the porous pot, so that it is advisable to place them when in use either outside on the window sill or in a cupboard that has access to the air.

The solutions rapidly run down after six or seven hours' work so that it is rarely the same solutions (the positive of which must be poured back into the bottle) are available a

second time, at any rate not if the full power of the cell is required.

Bichromate cells, when employed for spark coils, should be of the largest size and preferably of the flat shape, made up into a battery of six cells. The medium size Edison-Lalande battery (300 ampère hour's capacity) is an excellent cell for working large spark coils, especially as after use it can simply be stood on one side till next required. With the Bunsen and Grove batteries it is advisable not only to pour back the solutions but also to thoroughly rinse the different parts and carefully dry the terminals.

As regards the number of cells required for working coils, more than two will rarely be required for medical coils, while in most instances one will be sufficient.

With spark coils from three to six cells are usually employed, and more if required to increase the length of spark, but it must be borne in mind that with every cell added, after the proper number are connected up, the risk of breaking down the insulation of the secondary increases at a compound rate.

CHAPTER VIII.

FAULTS IN MEDICAL AND SPARK COILS.

FAULTS or break-downs in coils may be classed under the following five heads. The fault may be in—

(1) Primary winding,
(2) Secondary winding,
(3) Connections underneath base,
(4) Contact-breaker and terminals,
(5) Battery,

but wherever it may be, the great thing to be borne in mind is to alter, unwind, or unscrew nothing until perfectly sure in which portion of the coil the fault really is. A strict observance of this rule will oftentimes save a large amount of trouble and expense.

Faults in Primary.

Faults in the primary are generally confined to short circuits or breaks in the wire, and these most frequently occur at the two ends of the winding where they enter and leave the bobbin. If the contact-breaker refuses to act, or works only very feebly (and the battery is in good order), it will usually be found that a short circuit has formed somewhere in the primary winding whereby a number of the turns are cut out and the magnetism of the core consequently very feeble. If on testing the core there is found to be absolutely no magnetism and no spark when the battery wire is touched

momentarily on the primary terminal, it may safely be conjectured that the primary winding is broken somewhere. If the break in the wire is at one of the two points where it enters or leaves the bobbin it will be advisable to endeavour

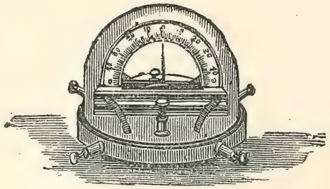


FIG. 118.—GALVANOMETER.

to neatly repair the break by a small bridge of solder, as it is only possible to get at the primary winding by first unwinding the secondary. In testing for faults both in the primary and secondary windings, a galvanometer (see Fig. 118) will be found very convenient as by this means the fault can quickly be located between any two points.

Faults in Secondary.

Faults in the secondary are naturally much more frequent and more difficult to cope with than those in the primary, owing to the high tension of the current. One of the most common secondary faults is a break-down in the insulation between one or more layers, or in bad cases, between the whole of the layers. This is generally caused by using too much battery power and endeavouring to get a very long spark, the ends of the secondary being gradually separated more and more until the spark finds it easier to pass between some two points inside the coil. Once the insulation is pierced the spark will in future follow this path unless the separation between the ends of the secondary wires is of less resistance. Breaks in the secondary wires occur, as in the primary, usually at the ends.

If the sparks at the ends of the secondary seem considerably diminished while the full battery power is on and the primary has been found to be in perfect order, it may generally be concluded that the insulation of the secondary has broken down. In many instances on separating the ends of the secondary beyond sparking distance, the sparks passing through the leak in the coil will distinctly be heard. This breaking down of the insulation of a coil is one of the most serious faults, as, if it does not render the coil useless, greatly diminishes its sparking capabilities. In most cases the only really effectual remedy is to rewind the secondary, but before doing this the following may be tried:—Remove the outer wrapping of the coil of velvet or whatever it may be, and then get ready some very hot paraffin wax and a hot, clean and pointed soldering iron. With the soldering iron endeavour to get the wax insulation between the inside of the cheek of the bobbin to run, and when this is the case thoroughly drench the space with the hot wax and continue to apply the wax until it soaks right through. Let the coil stand for 24 hours for the wax to thoroughly cool and set, when it should be tried to see if the leak has disappeared. If not, serve the other end of the bobbin in a like manner. By this method it is possible sometimes to cure a bad leak, the object being to run all the wax at the bobbin ends and ends of the layers together, as it is generally between the ends of the layers that break-downs in the insulation occur.

Faults in Connections.

Leaks between the connections in the base of the coil sometimes occur owing to the wires having perhaps moved, and these faults are more frequent in medical coils with three

windings and special switch on base to give the combined or separate shocks. Remedy: unscrew the bottom part of the base, test with battery and galvanometer to find the fault, and insulate same with paraffin wax or paper.

Faults in Contact-breaker and Terminals.

First thoroughly satisfy yourself that it is not merely a question of adjustment, after which remove bottom part of base and see that the connecting wires are making good connections to the contact-pillar and spring standard. Next inspect the platinum contacts to see that these have not worked loose and also that the circuit is complete through the different parts. Test also the circuit to the primary terminals and see that these latter are making firm connection with the connecting wires under the base.

Battery Faults.

Faults in the battery are soon found out, for if the wires from the two poles on being momentarily connected together do not give the customary short thick spark, the fault must be in the battery provided the connecting wires are sound. This latter point can be ascertained by connecting the poles by a fresh piece of wire. If the spark occurs on breaking the circuit the fault is in the connecting wires

The most common battery faults are exhausted exciting solution or solutions, dirty, corroded or loose connecting clamps, broken elements or porous pots. If the battery is a dry one the quickest plan is to remove the cells and obtain fresh ones from the manufacturers, who usually allow a certain amount for the exhausted ones. With the Bunsen battery the connecting clamps quickly corrode owing to the fumes, or else to being splashed with the solution. These must be cleaned up with emery paper or a file, and a little drop of oil should be put on the threads of the set-screw to prevent the acid corroding it and causing it to stick. Broken elements or porous pots can soon be detected on inspection.

Faults in Condensers.

The fault to which most condensers are liable is a breaking down of the insulation between the different layers of tin foil. Owing either to the use of inferior paper or by employing too much battery power the charge in the condenser sparks across the intervening layer of paraffin paper, piercing a hole; and after this has occurred it will continue so to spark until it is repaired. Although there are a large number of sheets of tin foil, it must be remembered that they are connected together in two sets amounting theoretically to two large sheets of tin foil pasted one each side of a sheet of paraffined paper, and that it is only necessary to have a perforation at one point to break down the whole of the condenser. The most prominent evidence of a break-down in the condenser is manifested by a reduction of the length of the secondary spark coupled with an increased brightness of the primary spark at the contact-breaker.

If a fault in the condenser is suspected it must be disconnected and the different sheets removed one by one and held up to a strong light until the perforated sheet is found. This sheet must then be replaced by a fresh one.

CHAPTER IX.

FIGURES PRODUCED BY ELECTRIC DISCHARGES ON PHOTOGRAPHIC PLATES.

Some curious effects are to be obtained from discharges from a spark coil passed over a photographic dry plate, and the following description of the first discoveries in this direction by Mr. J. Brown, of Belfast, which appeared in the *Philosophical Magazine* for December 1888, will be found of interest.

The results shown on the frontispiece are reproductions from figures kindly supplied by Mr. Brown, a description of whose coil will be found in the *English Mechanic* for February 27th, 1880.

"While photographing the electric discharge from an induction coil it occurred to me to try what effect would be produced on the plate by the discharge when taking place directly on the *sensitive film* itself.

"A rather rapid photographic dry plate was laid film upwards on a piece of sheet metal connected to one terminal of the secondary, whose ordinary discharging points were set about 3 centim. apart to act as a by-pass to the spark and prevent it striking over the edge of the plate. The end of a wire from the other terminal rested on the centre of the film. A single discharge from the coil was caused by moving its mercury-break by hand, and the plate was then placed in the developer.

"When the terminal wire at the centre of the plate was negative, and particularly if no discharge passed over the edge of the plate, the result was like that represented at A (Frontispiece), which shows the typical negative form, consisting of beautiful sharply defined symmetrical palm-like fronds on irregular stems branching out from the centre where the wire rested, together with a mass of less distinct irregular straggling lines also branching outwards, but not reaching so far as the fronds.

"When the wire terminal was made positive and a discharge caused under otherwise precisely similar conditions, the figure was quite different, as in B, and consisted on the plate of dark irregular branchings sharply defined, except near the centre, where apparently the luminosity of the spark has caused a nebulous edge to the branch. These branchings are accompanied by light irregular straggling radiations, similar to those on the negative plate, but having a rather more distinctly centrifugal direction and extending beyond the well-defined branches, from which they seem to be to some extent offshoots. The experiments were repeated several times and gave similar characteristic results. If, however, the metal sheet were omitted, and wires from both positive and negative terminals brought down on a plate insulated on a paraffin block, neither the palm-fronds on the negative, nor the dark markings on the positive appeared, but only the lighter irregular branchings, and these were in much greater quantity round the positive terminal than at the negative; but with the poles not too far apart they stretched across from one to the other in the form of confused and irregular lines of flow.

"When the plate was laid, as before, on a metal sheet and wires from both positive and negative terminals brought down on the film, a discharge produced the characteristic figures under their respective wires as shown at F. These were best defined only when no spark discharge crossed between the wires on the plate; and there was in this case no branching out of the positive and negative markings towards each other, the inductive circuit sensibly completing itself through the metal sheet under the plate.

"When the difference of potential was made sufficient to produce spark-discharge between the terminals on the plate, the resulting marking depended in several respects on the presence or absence of a metal sheet under the plate.

"With no metal sheet, and the plate insulated on a block of paraffin, the discharge took a fairly direct course between the terminals, with only slight crookedness, but sometimes in a double line. On this plate the characteristic palm-fronds of the negative and dark branchings of the positive pole are wanting, and the lighter tracery forms a rough indication of confused lines of flow between the poles.

"With a sheet of foil pasted on the back of the plate (leaving a margin of about 2 centim. round the edge) and spark-discharge between the terminals, there is exceedingly little, if any, distinct tendency of the positive and negative markings towards each other. The track of the main spark is very crooked, meandering over the plate in a quite irregular way, and making sometimes sharp distinct angles in its course. From about half of its length from each end, but principally from the terminals, branch off here and there the characteristic positive or negative markings.

"When a strip only of foil was fixed on the back of the plate so that its length crossed the line joining the pole at an angle of about 45°, and about twenty sparks were passed, they all took a similar S-shaped course, having been apparently attracted out of the direct line to follow that of the foil underneath the glass.

"The meandering form and general appearance of these sparks, when acted on inductively by the foil under the plates, remind one very much of certain kinds of lightning-flashes, and suggest at least a possibility of some similarity in the causes producing each.

"The question now arose as to whether the result was due to a photographic effect of the luminosity of the spark, or to some more direct action of the discharge on the film—to what might be called an 'electrographic' action.

"As evidence for the latter view came the apparent insufficiency of the light actually visible when the discharge took place to produce the effect. The lighter branchings were not to me visible at all in either positive or negative, and only an indication of the frond formations in the negative.

"There are also in the positive plate, B, several intervals, as if the spark had not been in immediate contact with the film, but had passed over it, leaving only a foggy mark instead of a sharply defined black line. The break or interval would scarcely have been so marked if the whole effect were photographic only.

"However, to further investigate this question the discharge was taken with the two terminals on the back or uncoated side of the plate. The figures which now appeared on the film were quite different from those described above. In each case there was impressed on the *back* of the film (next the glass) the cloudy photographic effect of the branching discharge on the back of the plate.

"On the front or outer side of the film under the positive terminal the figure reminded one of a photograph of a maiden-hair fern out of focus. That under the negative is a collection of peculiar tadpole-like markings, whose general arrangements correspond in size and shape to the fronds formed by the discharge on the back of the plate. These figures would appear to be due to electricity induced in the film.

"To try further the effect of induction on the film, I cut my initials in tin foil after the manner of a stencil plate, placed the foil on the film, a piece of gutta-percha tissue on the foil, and pressed all together in an ordinary photographic printing frame. A second piece of foil was placed on the back of the plate, leaving a margin all round, and the foils were joined to opposite poles of the coil with its terminals

giving a by-pass of about 1 centim., so as not to have any spark-discharge over the plate. The result with the poles connected in either sense, and the coil working for about a minute was, with the stencil foil either positive or negative, an irregular blackening all round the edge of the foil, including the edges of the cut-out parts, as if a discharge had passed out from the edges. In some places the characteristic markings of positive or negative, as the case might be, were visible. There was, however, a slight visible discharge from the edge of the foil on the back of the plate, and probably therefore the same from that on the film to which the edge-marking may be due. There was also on the plate much blotchy marking, apparently corresponding to the wrinkling of the foil in contact with the film.

"With a piece of gutta-percha tissue between the stencil-plate foil and the film, the result was similar, only the line round the edges was narrower and the blotching less marked, hence the initials came out more distinctly. When four thicknesses of gutta-percha were interposed, there appeared only blotchy markings on the part under the foil.

"These results would go to show that actual disruptive discharge over or in the film is not needed to produce an effect visible on development, but that the figures are produced partly, at least, by direct electric action on the sensitive film without the intervention of a visibly luminous action, or what would be usually understood as a purely photo-chemical cause. Possibly further investigation may show that we have here a new kind of experimental evidence on the relation of electricity to light.

"I may add that it is necessary, especially in the experiments with the terminals on the back of the plate, to use rather sensitive plates; '60 times' plates do very well, while slow plates give imperfect figures in all cases and show almost nothing with the terminals on the back."

CHAPTER X.

THE "X" RAY PHOTOGRAPHY.

It was while experimenting with an induction coil and a Crookes' vacuum tube as modified by Lenard, that Professor Röntgen, of Wurzburg, made the startling discovery that certain cathodic rays emanating from the tube were capable of passing through opaque substances with more or less ease according to their density, and furthermore that such rays were also capable of taking effect on photographic dry plates. Unable to properly classify or understand the nature of these rays, he called them "X" rays, and as Röntgen "X" rays they are now generally known.

In a vacuum tube, as pointed out in Chapter VI., the air from the inside of the tube is exhausted, but the exhaustion is not carried to any great extent, and it was not until Professor Crookes took up the study of highly exhausted tubes that the behaviour of the electric discharge in high vacua was thoroughly investigated.

To properly understand the effect of the secondary discharge of an induction coil in vacua, and how the ordinary electric spark which we see in air becomes gradually broadened out into a glow, it is necessary to experiment for a few minutes with a piece of apparatus known as the "electric egg." It consists of an egg-shaped glass jar, with a contact plate or "electrode," as it is called, at both ends, and provided with an attachment for an air pump, so that the interior may be gradually exhausted. The two wires of the secondary of the coil are attached one to each electrode, and the positive electrode is technically called the "anode," and the negative the "cathode." On starting the coil it will be observed that while there is air inside the glass jar the spark between the two electrodes takes place, as was the case in the air outside, but as the exhaustion is carried out, so the spark gradually broadens out until the discharge partakes of the form of broad bands of a bluish-violet light, the whole discharge between the two electrodes being egg-shaped in appearance. On air being admitted the discharge gradually contracts until it again merges into sparks.

If we closely inspect the discharge in an ordinary vacuum or Geissler tube, where the exhaustion is carried to a somewhat further extent than in the electric egg just described, and no gas of any description has been introduced, it will be noticed that around the "cathode" is a bluish-violet light, while from the "anode" there emanates a purple-red glow extending almost to the cathode, and separated only from the bluish-violet light by a small dark interval known as the Faraday "dark space."

On experimenting with a Crookes' tube, where the exhaustion is carried to a still further extent, the nature of the discharge rapidly changes, for while with the ordinary vacuum or Geissler tube the red glow from the anode and the blue glow from the cathode nearly meet, and the Faraday dark space is small in the Crookes' tube as the exhaustion is pushed further and further, so the glows from both the anode and the cathode diminish, until at the highest exhaustions the dark space almost entirely fills the tube, and the rays from the cathode only become visible by their impinging on the glass walls of the tube, where they produce a greenish-yellow fluorescence.

Apart from their colour, however, there is a vast difference in the nature of the rays from the cathode to those proceeding from the anode, for whereas in the Geissler and Crookes' tubes the purple-red glow of the anode follows all the windings of the tube, the cathode rays, at the higher exhaustions, pass in straight lines from the cathode and *in a direction perpendicular to its surface and irrespective of the position of the anode.*

As has been before stated, these cathode rays are themselves invisible to the naked eye, and become apparent only by the fluorescent effect they produce on the glass walls of the tube; and the "Shadow of the Cross" tube invented by Crookes not only sufficiently bears out this fact, but also proves that the cathodic rays move only in straight lines perpendicular to the surface of the cathode. In the "cross" tube above referred to the cathode is at one end of a pear-shaped bulb, and consists of a circular disc, while the anode is an aluminium cross situated at the opposite end, and so arranged that by a gentle tap the cross falls down flat against the bottom of the glass tube. When the tube is in action and the cross standing up, the portion of the glass not screened from the cathodic rays by the aluminium cross exhibits a yellow-green fluorescence, while the shadow of the cross remains dark owing to the absorption of the rays by the metal. By a slight tap the cross is now made to fall down clear of the cathode rays, and we now observe a lighter cross on a dark background, owing to the portion of the glass that was exposed having lost to a certain degree its power of fluorescing.

It was while experimenting with the cathodic rays from a Crookes' tube that Professor Röntgen discovered his "X" rays, and the discovery appears to have been quite accidental. Some photographic printing paper appears to have been lying on a bench near the Professor, who was experimenting with a Crookes' tube enclosed in a cardboard case, and it was found that the paper had been acted upon. This induced further experiments resulting in the discovery of the "X" rays, which appear to be different from the ordinary cathodic rays, as these latter do not pass into the air, being unable to

penetrate the glass. On further experimenting, it was found that the rays were capable of acting on photographic plates even when apparently opaque substances intervened, and the rays have proved very useful in determining the respective densities of various substances. It was further observed that when a piece of paper or cardboard smeared with barium platino-cyanide was brought into the neighbourhood of the tube, which was still enclosed in the cardboard box, the surface of the cardboard became brightly fluorescent, and though the "X" rays themselves were invisible, the shadows cast by substances of varying density became at once apparent.

The most important discovery, however, was that it was possible to take a photograph or shadowgraph of various parts of the body, showing the bones apparently completely denuded of the flesh, and it is rarely that a new discovery has been turned so rapidly to practical account as has been the application of the "X" rays to surgery. Not only is it possible to take a photograph of the hands, feet, &c., but by the use of a fluorescent screen, surgeons of to-day are enabled to at any time view the bony structure of the greater portion of the body, and thus detect malformations or the presence of foreign substances.

Like the cathodic rays, the "X" rays pass in straight lines perpendicular to the surface of the cathode, but are not diverted out of their course by a magnet, as is the case with the cathodic rays.

The exact nature of the "X" rays has not yet been ascertained, but they are thought by some to belong to the ultra-violet rays of the spectrum, though Röntgen has demonstrated that they are practically incapable of refraction or regular reflection.

FIG. 119.—REDUCTION FROM A WHOLE-PLATE PHOTOGRAPH OF THE WRITER'S HAND, 2 MINUTES' EXPOSURE, 4-INCH SPARK COIL.

Taking a Photograph.

The apparatus necessary to take an "X" ray photograph, shadowgraph, or skiagraph, as it is variously called, consists of an *induction coil* of not less than 2-inch spark, a *vacuum tube* of special construction, a suitable *battery* to work the coil, and a supply of rapid *dry plates.* The induction coil should not be less than 2-inch spark, owing to the exposure being tedious; a 4-inch spark is a very serviceable size, enabling a good definition to be obtained with about 3 to 4 minutes' exposure. The tube also must be of the very best quality to get satisfactory results.

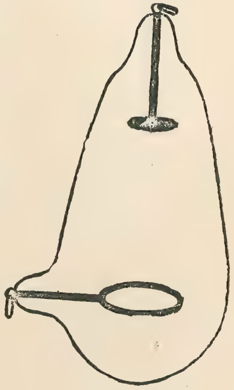


FIG. 120.

The first form of tube introduced is shown in Fig. 120, and the method of taking a photograph with this pattern tube is shown in Fig. 121. The photographic plate is first placed in the dark slide, or better still in an envelope of black paper, or if this is not at hand, in a sheet of brown paper. The coil and battery are then got ready and the tube connected up as shown, bearing in mind that the top plate is the cathode and the ring the anode, and that the "X" rays proceed in a straight line from the cathode. The tube must not be too near the hand, but about 6 inches above it. Previous to placing the plate under the tube the coil and tube must be tested, when, if the tube is working properly, it will be filled with a yellow-green fluorescence, and the shadow of the ring on the bottom of the glass bulb will be visible. Having got the coil and tube right, turn off the current, place the hand and plate in position, and again turn on current. After about three to ten minutes, according to the size of the coil and quality of the tube, the plate can be taken into the dark room and developed in the usual way. The photograph can be taken in broad daylight, though to use the fluorescent screen it is of course necessary for the room to be absolutely dark.

A great improvement has, however, been recently effected in the tubes by the introduction of what is known as the "focus" tube, which tube is illustrated in Fig. 122. It

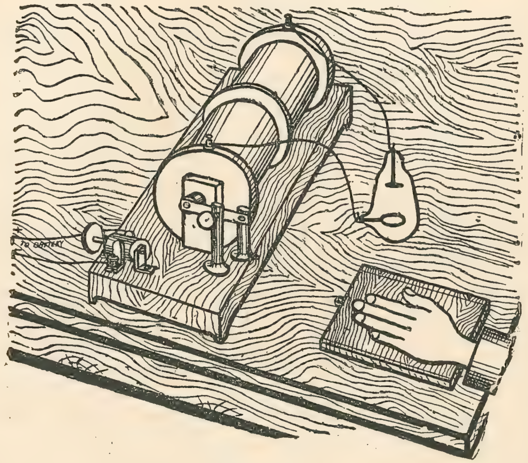


FIG. 121.

consists, it will be seen, of an egg-shaped bulb provided with a stem, by means of which it may be conveniently gripped in a tube-holder. The cathode consists of a conical disc, while the anode, which is in the centre of the tube, consists of an inclined plane set at an angle of 45° to the cathode. In the form of tube shown in Fig. 120, the rays from the cathode proceed straight from the surface of the cathode to the object to be photographed; but in the "focus" tube, by the conical

shape of the cathode, the rays are brought to a focus on the inclined plane and thence diverge at an angle of 45°, so that the tube must be used in a horizontal position.

In using the focus tubes, as soon as the current is turned on the inclined plane will rapidly become red hot. Keep the red spot on the plane small by reducing the current in coil, or altering the adjustment of contact breaker. The tube is working at its best when the red spot is just visible on the inclined plane.

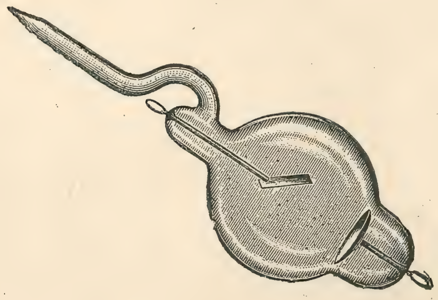


FIG. 122.—FOCUS TUBE.

On no account must the tube be touched with the hand while working.

If the red spot does not appear and the yellow-green glow in the tube is feeble, the tube is probably connected up the wrong way.

In selecting tubes for "X" ray work it is very important to get a reliable and trustworthy article, as an inferior tube is soon rendered useless; while, moreover, even when it is working, though apparently it may look to be of good quality, the exposure will be found to be unnecessarily long to get well defined results.

Fig. 123 shows a tube-holder for "focus" tubes, some form of which is absolutely necessary, as the tube cannot be held in the hand.

The handle part of the tube is gripped in the end of the tube-holder, the sides of which are faced with cork to get a better grip on the tube. The stem of the tube-holder has several joints, so as to allow the tube being readily adjusted to any position. Wires are run from the secondary terminals

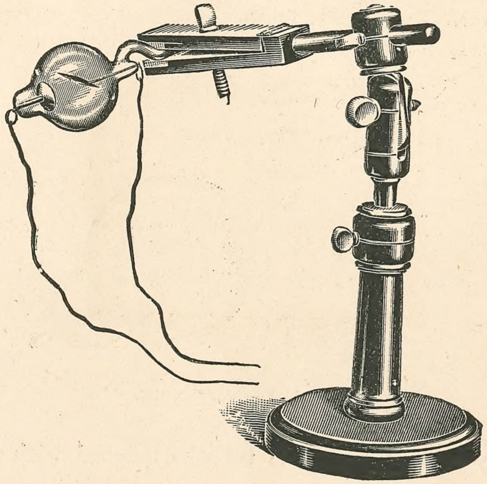


FIG. 123.—FOCUS TUBE AND HOLDER.

to the connections of the tube, and care must be taken to keep these wires well apart, as the tendency to spark from one to the other is of course very great.

Fluorescent Screens.

The "X" rays themselves are invisible, but their effects can be rendered apparent to the eye by means of fluorescent screens. These consist of wood frames of the required size,

carrying a sheet of cardboard the surface of which is pasted either with barium platino-cyanide or calcium tungstate, or other fluorescing material.

Fig. 124 shows a simple and convenient form of screen for ordinary use, the surface of which can either be pasted with barium platino-cyanide or calcium tungstate. A large number of different kinds of screens are now in the market, the main difference being chiefly in the manner in which the fluorescent material is applied, so as to get an even and regular surface. The best fluorescent materials so far dis-

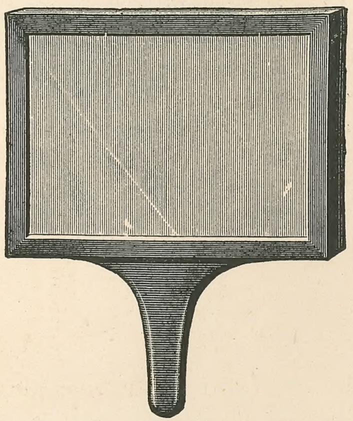


FIG. 124.—FLUORESCENT SCREEN.

covered are barium platino-cyanide and its kindred salt, potassium platino-cyanide, both being very expensive chemicals, especially the latter.

Fluorescent screens have been also very successfully employed for diminishing the exposure necessary in taking an "X" ray photograph, the fluorescent side of the screen being placed next to the sensitive film of the plate. By this means several experimenters have succeeded in greatly reducing the time of exposure.

"X" Rays in Surgery.

Unquestionably the most important use so far discovered for the "X" rays is in surgery, and it is very rarely that a new discovery has been so quickly turned to practical account. Most hospitals are now equipped with "X" ray apparatus, so that fractures of the bones can at once be viewed and more easily set. Foreign bodies in the flesh are very quickly located and extracted, and many cases where needles, bullets, &c., have been in the bodies of persons several years, have recently been successfully removed. In diseases of the joints, &c., the "X" rays have proved very useful, a photograph showing at once the enlarged joints and diseased bones. Several photographs have recently been taken of the skull, and also of the chest showing the ribs and heart *in situ.* The time of exposure has also been greatly reduced by recent experimenters, and Dr. McIntyre, of Glasgow, has succeeded in taking excellent photographs in two or three seconds with an 11-inch spark coil.

INDEX.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED
GREAT WINDMILL STREET, W., AND DUKE STREET, STAMFORD STREET, S.E.